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A Revised Radiolarian Zonation for the Upper Jurassic of Western North America

by

Emile A. Pessagno, Jr., Charles D. Blome, and Jose F. Longoria

Paleontological Research Institution
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A REVISED RADIOLARIAN ZONATION FOR THE UPPER JURASSIC OF WESTERN NORTH AMERICA*

By

EMILE A. PESSAGNO, JR.,[1] CHARLES D. BLOME,[2] AND JOSE F. LONGORIA[1]

ABSTRACT

An accurate radiolarian zonation for the Upper Jurassic is critical to unraveling the stratigraphy and tectonic history of much of western North America. To meet this end a revised zonation is presented for the Upper Jurassic of the California Coast Ranges. Zones 1, 2, 3, and 4 of Pessagno (1977a, 1977b) are redefined and related as accurately as possible to Upper Jurassic chronostratigraphic units. Discrepancies between European, Deep Sea Drilling Project, and North American biostratigraphic and chronostratigraphic data are analyzed. We conclude that many of the problems surrounding the correlation of North American Jurassic strata with those in the Mediterranean area are due to paleo-oceanographic factors closely related to plate tectonics. Even if preservational and taxonomic problems are excluded, correlation of Tethyan European Upper Jurassic radiolarian assemblages with those of either Boreal or Tethyan North America will continue to be a difficult problem. The southern European Tethyan faunas differ from Tethyan faunas of eastern Mexico by lacking *Parvicingula* Pessagno, 1977, and may be representative of a lower latitude province within the Tethyan Realm.

One new genus, *Vallupus* Pessagno and Blome, and four new species: *Vallupus hopsoni* Pessagno and Blome, *Hsuum mclaughlini* Pessagno and Blome, *Parvicingula colemani* Pessagno and Blome, and *P. excelsa* Pessagno and Blome, are described from volcanogenic-pelagic strata overlying the Stanley Mountain remnant of the Coast Range ophiolite. These taxa as well as many others are pertinent to the definition of Upper Jurassic zonal units in California and elsewhere in western North America.

INTRODUCTION

Nearly eighty years ago Steinmann (1905) stressed the genetic association of serpentinized peridotites, spilitic basalts, and radiolarian cherts ("Steinmann's Trinity"). This early observation perhaps prophesied the coming of the sea-floor spreading hypothesis and the importance of radiolarian biostratigraphy in tectonic studies.

The application of plate tectonics theory to the geology of complex mobile belts throughout the world has greatly accelerated geological investigations. However, until recently geologists were often hampered by a lack of biostratigraphic control at critical tectonic interfaces such as that between the Franciscan Complex and the Coast Range ophiolite in the California Coast Ranges. Geologic terranes of this sort are usually characterized by a paucity of invertebrate megafossils and an abundance of Radiolaria occurring in radiolarian cherts. In the past it was impossible to extract Radiolaria from radiolarian cherts; all Radiolaria had to be identified in thin-section. However, in 1972 Pessagno and Newport developed the simple hydrofluoric acid technique, which allows the extraction of matrix-free Radiolaria from cherts, tuffs, siliceous mudstones, and other siliceous rocks. The development of the HF technique and the introduction of the scanning electron microscope (SEM) provided technological breakthroughs that opened the door to the study of Mesozoic and Paleozoic Radiolaria.

Jurassic Radiolaria were first studied at the turn of the century. At that time monographic studies, which dealt both with Jurassic and Lower Cretaceous (Berriasian to Valanginian) Radiolaria were presented by Rüst (1885, 1898), Parona (1890), and Vinassa de Regny (1899). Curiously, no other comprehensive reports dealing with Jurassic Radiolaria were published until the 1970's (*e.g.*, Foreman, 1973; Pessagno, 1977a).

With the advent of the hydrofluoric acid technique (Pessagno and Newport, 1972), we were immediately supplied with a vast number of chert residues from localities all over the world. Unfortunately, at this time there was no independent way to date Jurassic and most Triassic radiolarian assemblages. Radiolarian chert terranes associated with subduction complexes are notorious for their lack of biostratigraphically useful megafossils like ammonites. Occasionally, however, pectenacids and conodonts occur in Triassic cherts, and calcareous microfossils such as calpionellids and nannoconids occur in pelagic limestones interbedded with Upper Jurassic and Lower Cretaceous radiolarian cherts in the Tethys.

Gradually, during the period from 1968 to the present time, biostratigraphic data that could be utilized to date Jurassic radiolarian assemblages accumulated from the Deep Sea Drilling Project (*e.g.*, Foreman,

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1973, 1975; Riedel and Sanfilippo, 1974) and from land-based sections (*e.g.*, Pessagno, 1977a, 1977b; Pessagno and Blome, 1980, 1982; Pessagno and Whalen, 1982). Pessagno, his colleagues, and students are now involved in analyses of Jurassic radiolarian faunas from western North America (Baja California, California, east-central Oregon, the Queen Charlotte Islands, Alaska, and east-central Mexico). The purpose of these investigations is to develop a detailed system of radiolarian zonation for the Upper Triassic and the Jurassic that can be integrated as closely as possible with that of the ammonites and other well-studied fossil groups.

A major stumbling block in completing this zonal scheme occurs in the Upper Jurassic (Oxfordian to Tithonian). In North America and indeed elsewhere in the world it is difficult to find Upper Jurassic strata that contain both abundant well-preserved Radiolaria and ammonites. In North America this problem may in part be resolved by studies recently initiated by Pessagno and Longoria in east-central Mexico. In this area Upper Jurassic strata ("Santiago", Taman, and Pimienta formations) contain common to abundant ammonites, pectenacids, calpionellids, nannoconids, and Radiolaria.

Pessagno (1976, 1977a, 1977b) presented the first detailed zonation for the Upper Jurassic (Kimmeridgian/Tithonian) to Upper Cretaceous (Maestrichtian) strata of western North America. As new biostratigraphic data accumulated from the Mediterranean area (Baumgartner, DeWever and Kocher, 1980), the deep sea, North America (Pessagno and Blome, in prep.), and Oman (Tippit, 1981), it rapidly became apparent that Pessagno's Upper Jurassic zonal units were in need of redefinition. Many zonal markers, for example, have been found to be longer ranging than previously believed.

To establish a detailed system of radiolarian zonation for the Upper Jurassic—closely integrated with that of the ammonites, calpionellids, and other established groups of fossils—is vital to the interpretation of the geology of the California Coast Ranges and a number of other areas in western North America. In California, for instance, it not only has a tremendous bearing on the age and time of emplacement of the Coast Range ophiolite, but also on the age of the Nevadian Orogeny (*cf.* Hopson, Mattinson, and Pessagno, 1981).

The purpose of this report is to redefine Zones 1, 2, 3, and 4 of Pessagno (1977a, 1977b), to describe new taxa that are important in the definition of Zone 4 in western North America, and to relate Zones 2, 3, and 4 insofar as possible to Upper Jurassic chronostratigraphic units. Finally, we will attempt to discuss discrepancies in the interpretation of European, Deep Sea Drilling Project, and North American biostratigraphic and chronostratigraphic data.

THE JURASSIC–CRETACEOUS BOUNDARY PROBLEM

The definition of the top of the Tithonian and in particular, the top of the Jurassic System remains a matter of considerable debate. Whereas catastrophic faunal changes occur at the base and top of the Triassic and at the top of the Cretaceous, those at the Jurassic–Cretaceous (Tithonian–Berriasian) boundary are insignificant. In theory, systemic boundaries should coincide with major rather than minor breaks in the paleontologic record. This sort of reasoning led Newell (1966, p. 75) to propose that Jurassic and Cretaceous strata might be included in a single supersystem. Wiedmann (1973, p. 177), in an excellent report dealing with changes in the ammonoid assemblage at Mesozoic system boundaries, found no evidence for a sharp faunal break either below or above the Berriasian. He proposed (p. 180) that the Jurassic–Cretaceous boundary be placed instead between the Berriasian and Valanginian and stated that "it would be placed—in analogy to the Triassic–Jurassic boundary—between the final extinction of Tithonian perisphinctids (Berriasellidae) and the origin of Neocomian perisphinctids (Neocomitinae) and the origin of Cretaceous Ammonitina (Desmoceratacеae)." In a later report Wiedmann (1980) included the Berriasian as the uppermost substage of the Tithonian and drew the Jurassic–Cretaceous boundary at the base of the Valanginian. It should be noted that the faunal change displayed by Radiolaria at the Jurassic–Cretaceous boundary is likewise of minor magnitude compared to that between the Permian and Triassic, the Lower and Middle Jurassic, and the Cretaceous and Tertiary. For the time being, however, we follow the traditional school of stratigraphy in our placement of the Jurassic–Cretaceous boundary between the top of the Tithonian and the base of the Berriasian.

DEFINITION AND SUBDIVISION OF THE TITHONIAN AND KIMMERIDGIAN STAGES

The Tithonian stage was first introduced by Oppel (1865), who unfortunately failed to designate a stratotype. As a result the term "Tithonian" has been used by a variety of investigators with completely different meanings. Until boundary stratotypes (*sensu* ISSC, 1970) are designated for this stage, it is likely that confusion about the definition of its upper and lower boundaries will continue.

Unbeknownst to most geologists and many geochronologists, the definition of the Tithonian and Kimmeridgian stages has been radically changed by ammonite biostratigraphers in recent years. According to Imlay (1980, pp. 31–32), the base of the Tithonian, as now defined by most workers, corresponds to the base of the Russian Volgian. This correlation is based on the local association of the Boreal/Tethyan ammonite *Gravesia* (Salfeld, 1913) with the Tethyan ammonite species *Hybonoticeras hybonotum* (Oppel, 1863). In Boreal northwestern Europe the base of the Tithonian is marked by the *elegans* Zone (Text-fig. 3; Imlay, 1980, p. 26).

The Tithonian has been subdivided into lower, middle, and upper units. Ammonite biostratigraphers disagree on which ammonite zones to assign to each of these three subdivisions (*cf.* Imlay, 1980, p. 27, fig. 16). Imlay (1980, p. 32), Enay (1964, pp. 363, 364; 1971, pp. 99, 100) and Enay and Geyssant (1975, p. 53) considered a bipartite division (*i.e.,* lower and upper) of the Tithonian to be more practical, particularly in correlations between North America and Eurasia. These workers define the base of the upper Tithonian by the first occurrence of calpionellids *s.l.* [= base of the *Chitinoidella* Zone of Remane (1969, 1978)]. Unfortunately, however, this biohorizon is difficult to recognize. *Chitinoidella* Doben, 1963, possesses a microgranular test wall whereas true calpionellids such as *Calpionella* Lorenz, 1902, possess a hyaline test wall comprised of radially arranged crystals of calcite. *Chitinoidella,* because of its test structure, does not lend itself to being preserved in limestones that are even mildly altered; calpionellids with hyaline tests are not as easily affected by minor diagenetic changes in Tethyan limestones. As a result, we choose to utilize the first occurrence of hyaline calpionellids (= calpionellids *s.s.*) to mark the base of the upper Tithonian. This biohorizon [= base of the *Crassicollaria* Zone of Remane (1969, 1978)] is easily recognized throughout the Tethyan Realm.

In Mexico (Sierra Cruillas, Tamaulipas) Bonet (1956, p. 82, locs. 44, 45, 48) recorded hyaline calpionellids from a horizon just below beds containing abundant ammonites assignable to Imlay's *Kossmatia–Durangites* Assemblage (see Imlay, 1980, p. 35: measured section at Loma Rinconada, Sierra Cruillas). He noted the presence of *Calpionella alpina* Lorenz, 1902, *C. elliptica* Cadisch, 1932, and *Tintinnopsella oblonga* (Cadisch, 1932) in these strata. According to Remane (1978, p. 166) the last two taxa are restricted to the Cretaceous (Berriasian and Berriasian to Valanginian, respectively). One must assume either that Bonet's data is out of date taxonomically or that *C. elliptica* and *T. oblonga* [= *Calpionellopsis oblonga* (Cadisch, 1932)] are longer ranging in North America than in Europe (*cf.* Remane, 1969, pp. 563, 568). Regardless of these two options, it is evident that hyaline calpionellids first appear below beds bearing Imlay's (1980) *Kossmatia–Durangites* Assemblage. In the Mediterranean area Zeiss (1984, p. 104) correlates this calpionellid event with the base of the *transitorius* Zone (Text-fig. 3). However, investigations by Pessagno and Longoria on the type Taman Formation (Taman–Tamazunchale area, San Luis Potosi) indicate that the first hyaline calpionellids (= base of the *Crassicollaria* Zone) occur immediately above the *Virgatosphinctes mexicanus–Aulacomyella neogeae* Zone and within the *Mazapilites* Zone of Cantu Chapa (1971). Furthermore, our Mexican studies indicate that the base of the *Crassicollaria* Zone corresponds closely to the base of radiolarian Zone 4 (see emended definition herein). In the California Coast Ranges the base of Zone 4 occurs below the first appearance of *Buchia piochii* (Gabb, 1869) and associated *Kossmatia*-bearing beds.

In the Boreal Realm of northwest Europe the top of the Tithonian is marked by the top of the *oppressus* Zone (Text-fig. 3); the base of the Berriasian is marked by the base of the *primitivus* Zone (Zeiss, 1984, p. 104). In the Tethyan Realm the top of the Tithonian is marked by the top of the *transitorius* Zone (central Tethys) or by the *Durangites* Zone (southern Tethys) (Text-fig. 3); the base of the Berriasian is marked by the base of the *euxinus* Zone (central and southern Tethys) (Zeiss, 1984, p. 104; Jeletsky, 1984, p. 99).

Problems arise in the correlation of ammonite faunas between North America and Europe and as a result, in the placement of the Tithonian–Berriasian boundary. In Mexico and California, Imlay (1980) utilized the top of his *Substeuroceras–Proniceras* Assemblage [= *Substeuroceras–Berriasella* Complex of Jeletsky (1984, p. 99)] and the equivalent *Buchia* sp. aff. *B. okensis* Zone (Jones, Bailey, and Imlay, 1969) to mark the top of the Tithonian. In Mexico, Imlay and Jones (1970, p. B9; see also Imlay, 1944a, p. 1017; 1944b, p. 1120; Jeletsky, 1984, p. 99) indicated that Berriasian strata overlying strata with the *Substeuroceras–Proniceras* Assemblage include *Subthurmannia tenochi* (Felix, 1891) and *Spiticeras zirkeli* (Felix, 1891). In California, Imlay and Jones (1970, pp. B12, 13) indicated that upper Tithonian strata including the *Substeuroceras–Proniceras* Assemblage and the equivalent *Buchia* sp. aff. *B. okensis* Zone are overlain by strata assignable to the *Buchia uncitoides* Zone. They indicated that the lower two-thirds of the *B. uncitoides* Zone is characterized by the presence of *Spiticeras* (*Negreliceras*) (Djanélidzé, 1922) and *Spiticeras* Uhlig,

1903, *s.s.*. Furthermore, these workers stated that

> the subgenus *Negreliceras* is characteristic of the Berriasian, is represented by only one species from the upper Tithonian, and is unknown from the Valanginian (Djanélidzé, 1922, pp. 48, 49, 51). The subgenus *Spiticeras* ranges from the top of the Tithonian through the Berriasian but no higher (Djanélidzé, 1922, p. 51). On the basis of the ammonites, therefore, most of the *Buchia uncitoides* Zone (lower two-thirds) in California cannot be younger than Berriasian and is unlikely to be as old as Tithonian. The upper third of the *B. uncitoides* Zone, however, has not furnished ammonites and could be younger than Berriasian.

Zeiss (1984, p. 104), however, disagrees with the correlations of Imlay (1980), Jones, Bailey, and Imlay (1969), and Jeletsky (1984). He correlated North American strata with the *Substeuroceras–Proniceras* Assemblage and *Buchia* sp. aff. *B. okensis* (Pavlow, 1907) with the *occitanica* Zone of the European Berriasian (Tethys). Furthermore, he correlated underlying strata with *Buchia piochii* (Gabb, 1869), *Parodontoceras* Spath, 1923, and *Buchia fischeriana* (d'Orbigny, 1844) with the *euxinus* Zone (see above). Zeiss maintained that the *Substeuroceras–Proniceras* Assemblage (Imlay, 1980)/*Substeuroceras–Berriasella* Complex (Jeletsky, 1984) does not include *Kossmatia* Uhlig, 1907, and *Durangites* Burckhardt, 1912. However, data presented by Verma and Westermann (1973, pp. 125, 129, 131, 134, 135) for the Sierra Catorce (San Luis Potosi) of eastern Mexico indicate that the *Substeuroceras–Proniceras* Assemblage not only includes these two taxa, but also *Microacanthoceras* Spath, 1925, *Corongoceras* Spath, 1925, and *Berriasella* Uhlig, 1905, as well. In Europe, the ranges of *Durangites, Microacanthoceras,* and *Corongoceras* do not extend above the Tethyan *Durangites* Zone.

One must assume that the absence of *Kossmatia, Durangites, Corongoceras,* and *Microacanthoceras* within the *Substeuroceras–Proniceras* Assemblage at other North American localities is either due to unknown paleoecological parameters or due to insufficient collecting. It is also possible that only the lower portion of the stratigraphic interval marked by the *Substeuroceras–Proniceras* Assemblage bears these Tithonian ammonites.

Until these problems are reconciled in the North American succession, we choose to follow the correlations of Imlay (1980) and Jeletsky (1984) in defining the top of the Tithonian. Furthermore, it is apparent that a more integrated study of the calpionellid, nannoconid, radiolarian, buchiid, and ammonite faunas both in North America and Europe is needed to resolve the Tithonian–Berriasian boundary problem.

Finally, it should be noted that if the base of the Tithonian is defined by the base of the *hybonotum* Zone in the European Tethyan Realm and by the base of the *Gravesia* Zone in the European Boreal Realm (= base of English *elegans* Zone), all of the Portlandian plus the middle and upper Kimmeridgian of Arkell (1956) would be included in the Tithonian (*cf.* Text-fig. 3). The Kimmeridgian is therefore restricted to the lower Kimmeridgian of Arkell (1956, pp. 21, 22). So redefined, the top of the Kimmeridgian in northwestern Europe would be marked by the *autissidorensis* Zone and its base by the *baylei* Zone (Text-fig. 3). In the central and southern Tethys the top of the Kimmeridgian is delineated by the top of the *beckeri* Zone and its base by the base of the *platynota* Zone (Text-fig. 3). In this report we follow Imlay (1980) in dividing the Kimmeridgian into only upper and lower divisions. Accordingly, the lower Kimmeridgian in northwestern Europe includes the interval from the base of the *baylei* Zone to the top of *cymodoce* Zone; the upper Kimmeridgian includes the interval from the base of the *mutabilis* Zone to the top of the *austissiodorensis* Zone (Text-fig. 3). In the European Tethys the lower Kimmeridgian includes the interval from the base of the *platynota* Zone to the top of the *divisum* Zone whereas the upper Kimmeridgian corresponds to the interval between the base of the *acanthicum* Zone and the top of the *beckeri* Zone (Text-fig. 3). Associations with ammonites and *Buchia* Rouillier, 1845 from equivalent intervals in the Kimmeridgian of North America are shown in Text-figure 3.

EMENDATION OF UPPER JURASSIC RADIOLARIAN ZONAL UNITS

Taxa that are used as the primary means of defining a zonal unit in this report are referred to as "primary marker taxa". Primary marker taxa are selected because they are distinctive in character, because they have sturdy tests that are likely to be preserved in a variety of rock types, and preferably because they have been observed at more than two localities in both the Boreal and Tethyan realms. Taxa used as a secondary means of defining a zonal unit are referred to as "supplementary marker taxa." Generally speaking, these taxa are not as distinctive or have been observed at fewer localities. However, in the absence of the primary marker taxa they may be used with a lower level of confidence in helping to delimit a given zonal unit. Other taxa that make their first or last appearance within the body of a zonal unit are referred to as "corporeal taxa" [from *corporeal* (adj.) = of the body]. It should be emphasized that the formal definition of a given zonal unit herein is based on the primary marker taxa and not on the supplementary marker taxa. The terms "interval zone" and "Oppel zone" used in the definition of the zonal units below are used in the sense of ISSC (1971).

ZONE 4
(**Ristola altissima** Zone)

Type of zone.—Oppel zone (see Text-fig. 1).

Primary marker taxa.—

Base: First appearance of *Parvicingula colemani* Pessagno and Blome, n. sp.

Top: Final appearance of *Ristola altissima* (Rüst, 1885) and *R. procera* (Pessagno, 1977a).

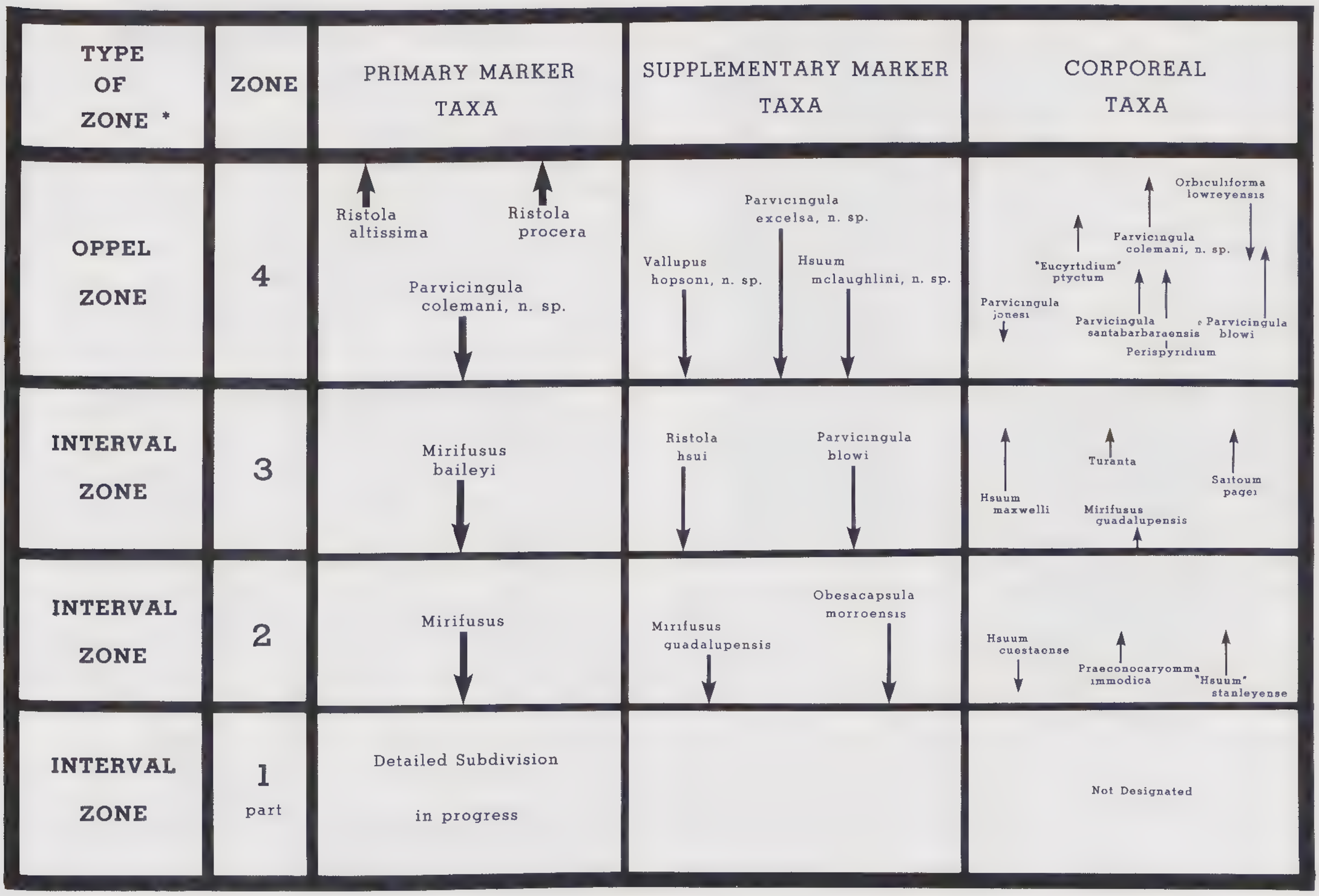
Supplementary marker taxa.—

Base: First appearance of *Vallupus hopsoni* Pessagno and Blome, n. sp., *Parvicingula excelsa* Pessagno and Blome, n. sp., and *Hsuum mclaughlini* Pessagno and Blome, n. sp.

Top: None utilized.

Corporeal taxa.—"*Eucyrtidium*" *ptyctum* Riedel and Sanfilippo, 1974, *Parvicingula colemani* Pessagno and Blome, n. sp., *Parvicingula jonesi* Pessagno, 1977b, *P. santabarbaraensis* Pessagno, 1977a, *P. blowi* Pessagno, 1977a, *Perispyridium* Dumitrica, 1978, and *Orbiculiforma lowreyensis* Pessagno, 1977a (see Text-fig. 1). The initial or final appearance of these taxa offers a means of further subdividing Zone 4. It should be noted that two corporeal taxa, *Perispyridium* (*P. ordinarium* Pessagno, 1977a) and "*E.*" *ptyctum,* that make their final appearance within Zone 4, are rare to very rare where we have observed them in samples from California and Baja California Sur. However, in east-central Mexico (loc. MX-82-37; see Locality Descriptions) strata assignable to the lower part of Zone 4 contain common *Perispyridium* spp. and no specimens of "*E.*" *ptyctum.*

Discussion.—In California the base of Zone 4 can best be observed in the volcanogenic-pelagic succession at Alamo Creek 90.2 m (296 ft) above the contact with the Stanley Mountain remnant of the Coast Range ophiolite (locs. SA-39; 81-CB-22; see Text-fig. 2; Locality Descriptions). The top of Zone 4 can best be



Text-figure 1.—Emendation of radiolarian zones 2, 3, and 4 (Pessagno, 1977a). The terms "Oppel zone" and "interval zone" are used in the sense of the International Subcommission on Stratigraphic Classification (1971). *Primary marker taxa* refer to taxa used as the primary means of defining a zonal unit. Taxa which are used as a secondary means of defining a zonal unit are referred to as *supplementary marker taxa.* In the absence of primary marker taxa supplementary marker taxa may be used with a lower level of confidence in delimiting a zonal unit. *Corporeal taxa* include taxa which make their first or last appearance within the body of a zonal unit. The relationship between the radiolarian zones, ammonite zones, and Upper Jurassic chronostratigraphic units is shown in Text-figure 3.

observed in the Great Valley sequence of Northern California at Grindstone Creek (Glenn County) and McCarty Creek (Tehama County) where it conforms closely to the top of the upper Tithonian *Buchia* sp. aff. *B. okensis* Zone (Jones, Bailey, and Imlay, 1969; Pessagno, 1977b). At Grindstone Creek rare *Ristola procera* (Pessagno, 1977a) occurs at loc. NSF-804 and abundant *R. procera* and rare *R. altissima* (Rüst, 1885) occur at loc. NSF-805. *Buchia* sp. aff. *B. okensis* (Pavlow, 1907) and *Lytoceras* sp. were collected from underlying strata at loc. NSF-803 (identifications by D. L. Jones, USGS; see Locality Descriptions). The first specimens of *Buchia uncitoides* (Pavlow, 1907) occur in overlying strata at loc. NSF-808. At McCarty Creek sample loc. NSF-838 occurs in the uppermost part of the *Buchia* sp. aff. *B. okensis* Zone just below the contact with the overlying *B. uncitoides* Zone of the Berriasian. Rare specimens of *R. procera* occur at loc. NSF-838 but were not observed in overlying strata assignable to the *B. uncitoides* Zone (Pessagno, 1977b, fig. 2).

In east-central Mexico, Zone 4 Radiolaria have been observed at locality MX-82-37 in the upper, thin-bedded portion of the Taman Formation [= lower Pimienta of Cantu Chapa (1971); see Locality Descriptions]. The radiolarian assemblage at this locality includes *Parvicingula colemani* Pessagno and Blome, n. sp., *Hsuum mclaughlini* Pessagno and Blome, n. sp., common *Perispyridium* spp., *Vallupus hopsoni* Pessagno and Blome, n. sp., and *Acanthocircus dicranocanthos* (Squinabol, 1914). The concurrence of *Perispyridium* (Dumitrica, 1978), with *Parvicingula jonesi* suggests an equivalence to the lower part of Zone 4. The MX-82-37 horizon occurs above the final occurrence of the pectenacid *Aulacomyella* Furlani, 1910, and hence is above the *Virgatosphinctes mexicanus–Aulacomyella neogeae* Zone of Cantu Chapa (1971). Cantu Chapa's *V. mexicanus–A. neogeae* Zone includes the uppermost part of the lower, more massively-bedded portion of the Taman Formation, whereas his overlying *Mazapilites* Zone includes the lower part of the upper, thin-bedded portion of Taman Formation in its type area. It can be established from preliminary investigations by Longoria that hyaline calpionellids assignable to the lower part of Zone A [= *Crassicollaria* Zone of Remane (1969, 1978)] occur in the lowermost part of the upper, thin-bedded Taman Formation. As a result, by the definition of lower and upper Tithonian utilized herein, the MX-82-37 horizon and part or all of Cantu Chapa's *Mazapilites* Zone should be assigned to the upper Tithonian.

ZONE 3
(**Mirifusus baileyi** Zone)

Type of zone.—Interval zone (see Text-fig. 1).

Primary marker taxa.—

Base: First appearance of *Mirifusus baileyi* Pessagno, 1977a. See discussion below and Systematic Paleontology.

Top: The top of Zone 3 occurs immediately below the biohorizon defined by the first occurrence of the primary marker taxa defining the base of Zone 4.

Supplementary marker taxa.—

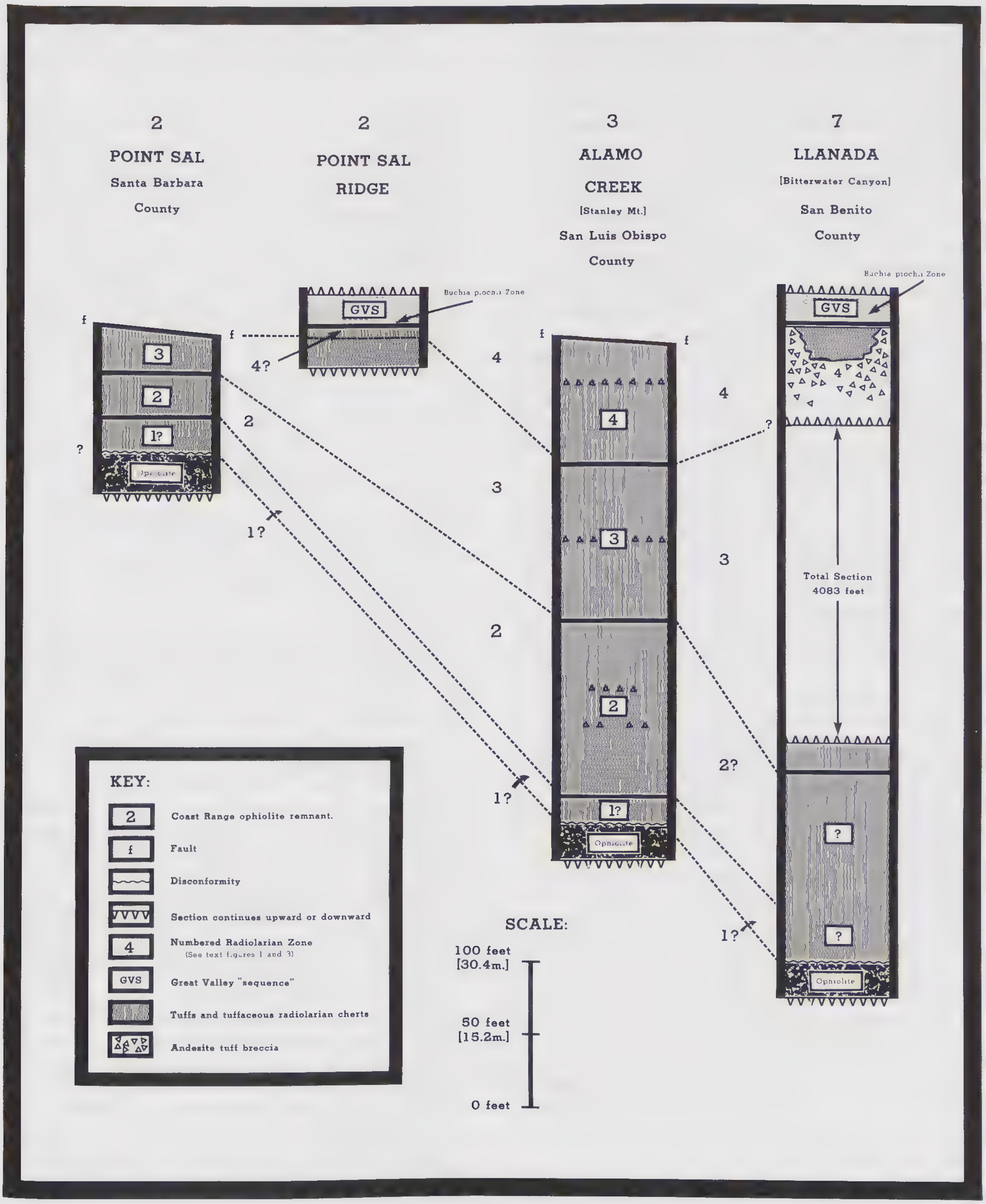
Base: First appearance of *Parvicingula blowi* Pessagno, 1977a and *Ristola hsui* (Pessagno, 1977a).

Corporeal taxa.—*Turanta* Pessagno and Blome, 1982, *Mirifusus guadalupensis* Pessagno, 1977a, *Hsuum maxwelli* Pessagno, 1977a, *s.s., Saitoum pagei* Pessagno, 1977a (see Text-fig. 1).

Discussion.—Pessagno (1977a) originally believed that *Mirifusus baileyi* Pessagno, 1977a, evolved from *M. guadalupensis* Pessagno, 1977a. We now believe that *M. baileyi* evolved from a *M. mediodilatata* (Rüst, 1885) ancestor. Baumgartner, DeWever, and Kocher (1980) include *M. baileyi* under *M. mediodilatata*. Our investigations indicate that these taxa are not only distinct morphologically, but also have significantly different ranges. In continuous sections at Point Sal and Alamo Creek (Stanley Mountain), *M. baileyi* always makes its first appearance well above that of *M. mediodilatata* (Text-fig. 2). At Point Sal, for example, *M. mediodilatata* first occurs at loc. NSF-904 and *M. baileyi* first occurs at loc. NSF-908 at 4.5 m (15 ft) and 13.4 m (44 ft), respectively, above the contact with the Coast Range ophiolite (*cf.* Pessagno, 1977a, text-fig. 3b). Detailed studies (Pessagno and Blome, in prep.) at Alamo Creek (Stanley Mountain remnant, Coast Range ophiolite) indicate that *M. mediodilatata* first

Text-figure 2.—Correlation of volcanogenic-pelagic strata above the Coast Range ophiolite at Point Sal (Santa Barbara County), Alamo Creek (San Luis Obispo County), and at Llanada (San Benito County, California). Numbering of localities 2, 3, and 7 corresponds to that used by Hopson, Mattinson, and Pessagno (1981). The reader is referred to the above report for a more detailed lithostratigraphic summary at these localities.

Note that at Llanada (loc. 7) lenticular masses of green tuffaceous radiolarian chert in tuff breccia rest in sedimentary contact beneath strata of the Great Valley sequence containing *Buchia piochii* (Gabb, 1869). The cherts contain a radiolarian assemblage assignable to the lower part of Zone 4 (upper Tithonian). Note also that the lower part of the succession above the Coast Range ophiolite at Point Sal (loc. 2) and Alamo Creek (loc. 3) is often too recrystallized to yield a significant number of identifiable Radiolaria. Hence, the absence of *Mirifusus* Pessagno, 1977a (first occurrence marks base of Zone 2), in the lowermost part of the Point Sal and Alamo Creek sequences may be diagenetically controlled.


2
POINT SAL
Santa Barbara
County
2
POINT SAL
RIDGE
3
ALAMO
CREEK
[Stanley Mt.]
San Luis Obispo
County
7
LLANADA
[Bitterwater Canyon]
San Benito
County
Buchia piochi Zone
GVS
f
3
2
1?
Ophiolite
4?
4
3
2
1?
Buchia piochi Zone
GVS
4
3
2
1?
Ophiolite
4
?
3
Total Section
4083 feet
2?
1?
Buchia piochi Zone
GVS
4
?
?
Ophiolite
KEY:
2 Coast Range ophiolite remnant.
f Fault
Disconformity
Section continues upward or downward
4 Numbered Radiolarian Zone
(See text figures 1 and 3)
GVS Great Valley "sequence"
Tuffs and tuffaceous radiolarian cherts
Andesite tuff breccia
SCALE:
100 feet
[30.4m.]
50 feet
[15.2m.]
0 feet

appears at loc. NSF-972, whereas *M. baileyi* first appears at loc. SA-31. These samples occur at 21 m (69.5 ft) and 62.1 m (204 ft), respectively, above the contact with the ophiolite.

A reanalysis of the samples studied by Pessagno (1977a) indicates that at Point Sal *M. guadalupensis* actually ranges above the base of Zone 3. *M. guadalupensis* occurs at loc. NSF-908 and loc. NSF-909, 13.4 m (44 ft) and 15.8 m (52 ft), respectively, above the contact with the ophiolite. Thus, an interval of concurrence exists between the first occurrence of *M. baileyi* and the final occurrence of *M. guadalupensis* in the lower part of Zone 3. To date, we have not observed the concurrence of *M. baileyi* and *M. guadalupensis* in the Alamo Creek section (Text-fig. 2).

It should be noted that Subzone 2B of Pessagno (1977a, 1977b) is included herein in the lower part of Zone 3. The top of this subzone and accordingly, the top of Zone 2 were first defined by the final appearances of *Emiluvia hopsoni* Pessagno, 1977a, *Perispyridium ordinarium* (Pessagno, 1977a), and *Hsuum maxwelli* Pessagno, 1977a, *s.s.* Studies of the volcanogenic-pelagic succession at Alamo Creek indicate that *P. ordinarium* and *E. hopsoni* range into the lower part of Zone 4 (loc. SA-43B; see Locality Descriptions). The final appearance of *H. maxwelli s.s.* remains the only one of Pessagno's original criteria for defining the top of Subzone 2B. We feel that it is unwise to delimit the top of a zonal unit on the basis of a taxon that is not distinctive.

ZONE 2
(**Mirifusus guadalupensis** Zone)
[formerly Subzone 2A of Pessagno (1977a, 1977b)]

Type of zone.—Interval zone (see Text-fig. 1).

Primary marker taxa.—

Base (only): First appearance of *Mirifusus* Pessagno, 1977a.

Top: The top of Zone 2 occurs immediately below the biohorizon defined by the first occurrence of *Mirifusus baileyi* Pessagno, 1977a.

Supplementary marker taxa.—

Base (only): First appearance of *Mirifusus guadalupensis* Pessagno, 1977a, and *Obesacapsula morroensis* Pessagno, 1977a.

Corporeal taxa.—"*Hsuum*" *stanleyense* Pessagno, 1977a, *Hsuum cuestaense* Pessagno, 1977a, *Praeconocaryomma immodica* Pessagno and Poisson, 1981 (see Text-fig. 1).

Discussion.—In continuous volcanogenic-pelagic successions at Point Sal (Santa Barbara Co., Calif.) and Alamo Creek (San Luis Obispo Co., Calif.) *Mirifusus* Pessagno, 1977a, first occurs somewhat above the contact with the underlying Coast Range ophiolite. At Point Sal *Mirifusus* is first recorded at loc. NSF-904, 4.5 m (15 ft) above the contact with the ophiolite. At Alamo Creek *Mirifusus* is first recorded at loc. SA-5, 4.7 m (15.5 ft) above the contact with the underlying ophiolite. Because strata at both localities become more recrystallized below the horizons with *Mirifusus,* its absence may be controlled diagenetically. "*Eucyrtidium*" *ptyctum* Riedel and Sanfilippo, 1974, first occurs at the base of the section at Point Sal (loc. NSF-900; *cf.* Pessagno, 1977a). It is now clear from our North American studies that this taxon makes its first appearance below the first occurrence of *Mirifusus* and accordingly the base of Zone 2.

ZONE 1
(**Parvicingula** Zone)

Type of zone.—Interval zone (see Text-fig. 1).

Primary marker taxa.—

Base: First occurrence of *Parvicingula* Pessagno, 1977a.

Top: On an interim basis, the top of Zone 1 occurs immediately below the biohorizon defined by the first occurrence of *Mirifusus* Pessagno, 1977a.

Supplementary marker taxa.—

Base (only): First occurrence of *Perispyridium* Dumitrica, 1978.

Discussion.—This zonal unit is in the process of being divided into subzones (Pessagno, Blome, Whalen, and Cheng, in prep.). At least eight subzones can be recognized for the Aalenian, Bajocian, Bathonian, and Callovian from studies nearing completion in east-central Oregon and Alaska. Studies of radiolarian-bearing strata in east-central Mexico should allow us to subdivide the Oxfordian and Kimmeridgian portions of Zone 1.

As noted by Hopson, Mattinson, and Pessagno (1981), "Zone 0" of Pessagno (1977a, 1977b) has been abandoned and is in effect encompassed by the upper part of Zone 1.

Criteria for defining the base of Zone 5 of Pessagno (1977b) are still being re-evaluated. For the time being, the base of Zone 5 is considered to occur above the final occurrences of *Ristola altissima* (Rüst, 1885) and *R. procera* (Pessagno, 1977a). The top of Zone 5 is as defined by Pessagno (1977b).

INTEGRATION OF BIOSTRATIGRAPHIC AND CHRONOSTRATIGRAPHIC DATA

Ristola altissima–R. procera final occurrence events (top of Zone 4)

In the California Coast Ranges these events correspond closely to the top of the Tithonian and to the top of the *Buchia* sp. aff. *B. okensis* Zone (Jones, Bailey, and Imlay, 1969). According to Imlay and Jones (1970, p. B12) "The beds in California that contain *Buchia* aff. *B. okensis* (Pavlow [, 1907]) are considered to be of latest Jurassic (late Tithonian) age because they contain the ammonites *Substeueroceras* [Spath, 1923], *Parodontoceras* [Spath, 1923], *Blanfordiceras* [Cossmann, 1907], *Proniceras* [Burckhardt, 1919], and *Spiticeras* (*Spiticeras*) [Uhlig, 1903] and are stratigraphically just beneath a sequence characterized by the pelecypod *Buchia uncitoides* (Pavlow [, 1907]) and the ammonite *Spiticeras* (*Negreliceras*) [(Djanélidzé, 1922)]."

Baumgartner, DeWever, and Kocher (1980, p. 45) indicate that the top of their "Biochronozone" C is dated by calpionellids as late Tithonian and that the base of their Biochronozone D is dated by calpionellids as early Berriasian (Early Cretaceous). The top of Biochronozone C of these workers also corresponds to the final occurrence of *Ristola altissima* (Rüst, 1885).

"*Eucyrtidium*" *ptyctum* final occurrence event

Davila (in prep.) has found "*E.*" *ptyctum* Riedel and Sanfilippo (1974) occurring with *Parvicingula colemani* Pessagno and Blome, n. sp., *P. jonesi* Pessagno, 1977b, *Ristola altissima* (Rüst, 1885), and other taxa common to Zone 4 in the lower part of the Eugenia Formation (Baja California Sur). Significantly, this assemblage was extracted from limestone nodules also containing common *Buchia piochii* (Gabb, 1869) and is, hence, late Tithonian in age. "*E.*" *ptyctum* is rare in Zone 4 strata both in Baja California Sur and in California (*e.g.*, locs. SA-39 to SA-43B; Alamo Creek; see Locality Descriptions herein).

Data presented by Baumgartner, DeWever, and Kocher (1980, table 3b) for the Mediterranean area and various deep sea sites and data from California likewise seem to indicate that "*E.*" *ptyctum* becomes extinct below the top of the Tithonian.

Parvicingula jonesi first occurrence event

In California *P. jonesi* Pessagno, 1977b, has never been found below the *Buchia piochii* Zone (upper Tithonian). In the Lowrey area of the northern Coast Ranges it has been only observed as low as the middle part of the *B. piochii* Zone (loc. NSF-821). However, in the Geysers–Clear Lake area (*cf.* McLaughlin and Pessagno, 1978), it has been observed 76 m (249 ft) above the depositional contact with the Coast Range ophiolite at locality MG-77-3. Radiolaria occurring at this locality, in addition to *P. jonesi*, include *P. colemani* Pessagno and Blome, n. sp., *P. excelsa* Pessagno and Blome, n. sp., and *P. blowi* Pessagno, 1977a. Elsewhere in the same area strata that rest in depositional contact on the Coast Range ophiolite contain *B. piochii* (Gabb, 1869) and possibly represent the lower part of the *B. piochii* Zone (loc. 17 of McLaughlin and Pessagno, 1978, p. 722, table 2).

No specimens of *P. jonesi* Pessagno, 1977b, were observed in the continuous volcanogenic-pelagic successions above the Coast Range ophiolite at Point Sal or at Stanley Mountain (Alamo Creek) (*e.g.*, locs. SA-39 through SA-43; see Locality Descriptions). Furthermore, we have not observed *P. jonesi* where lower Zone 4 volcanogenic-pelagic strata immediately underlie Great Valley sequence strata containing *B. piochii* (Gabb, 1869). At Llanada (Bitterwater Canyon; loc. SA-58), this contact is clearly a depositional contact.

In east-central Mexico near the village of Taman, San Luis Potosi, *Parvicingula jonesi* Pessagno, 1977b, occurs in a lower Zone 4 assemblage that is assignable to the *Mazapilites* Zone of Cantu Chapa (1971) (see p. 11 and loc. MX-82-37, Locality Descriptions).

Mirifusus first occurrence event

North America.—New biostratigraphic data from east-central Mexico and Northern California indicate that the first occurrence of *Mirifusus* Pessagno, 1977a, and accordingly the base of Zone 2 occurs in the uppermost part of the lower Kimmeridgian or in the upper Kimmeridgian. Jones (1975, p. 330) found *Buchia rugosa* (Fischer, 1830–1837) in the California Coast Ranges near Paskenta (loc. 74-JP-1 of Jones; see Locality Descriptions). Imlay (1980, p. 63) stated that "Assignment to the late Kimmeridgian is also favored by the presence of a few specimens that bear very fine ribs, as on *B. concentrica* (Sowerby), and by the absence of *B. mosquensis* (Von Buch) (D. L. Jones, oral communication, 1975), an associate of *B. rugosa*, which becomes more common upward." The absence of *B. mosquensis* (Von Buch, 1844) from the assemblage does not appear to be a significant factor. *B. mosquensis* sometimes occurs with *B. concentrica* (Sowerby, 1827) in both Mexico and northern Alaska. Imlay (1980, pp. 30, 31) noted that Burckhardt (1906, pp. 144, 155; 1912, pp. 50, 67, 80) recorded species of "*Aucella*" which are now referred to as *B. concentrica* and *B. mosquensis* in the lower part of a bed containing *Glochiceras* sp. cf. *G. fialar* (Oppel, 1862–63). In northern

Alaska Imlay (1955, p. 83) noted an association of *B. concentrica, B. mosquensis,* and *B. rugosa* (Fischer, 1830–1837) at USGS Mesozoic localities 22761 and 22766. From other data presented by Imlay (1980, pp. 24, 25; fig. 15) it would appear that the top of the horizon of concurrence (= final appearance of *B. concentrica*) of all three species of *Buchia* equates with the top of the horizon characterized by the presence of *Glochiceras fialar*; the base of the horizon of concurrence (= first occurrence of *B. rugosa* and *B. mosquensis*) is questionably correlated with the base of the *G. fialar* "Zone" (Text-fig. 3). The *Glochiceras fialar* Assemblage is in turn correlative with the *eudoxus* Zone and the underlying *mutabilis* Zone of northwestern Europe and the *eudoxus* and *acanthicum* zones of the Tethys (Text-fig. 3).

The association of *B. rugosa* (Fischer, 1830–1837) at locality 74-JP-1 (Jones, 1975) with some specimens that are transitional to *Buchia concentrica* (Sowerby, 1827) suggests an equivalence to the interval of *Buchia* concurrence discussed above. Pessagno (1977a) originally assigned the Radiolaria from the Jones's *Buchia rugosa* locality to his Subzone 2A (= Zone 2 herein) and noted the presence of *Hsuum cuestaense* Pessagno, 1977a, and "*H.*" *stanleyense* Pessagno, 1977a. Recently, a fragment of *Mirifusus* sp. was found during a careful re-examination of the residue.

Mirifusus Pessagno, 1977a, also occurs in the type Taman Formation (Heim, 1926) of east-central Mexico. In its type area near the village of Taman, San Luis Potosi, the Taman Formation can be divided into an upper thin-bedded limestone unit and a lower more massively-bedded unit. The lower more massively-bedded unit is characterized by the presence of limestone concretions in its upper part. *Mirifusus* was recovered at locality MX-82-8 from the lower, more massively-bedded unit. Investigations recently initiated by Pessagno and Longoria indicate that the MX-82-8 horizon is slightly above the first occurrence of *Aulacomyella* (Furlani, 1910). According to Cantu Chapa (1971, p. 27; see also Imlay, 1980, p. 31) *Aulacomyella* ranges from his *Idoceras* Zone (= upper lower Kimmeridgian) to his *Virgatosphinctoides mexicanus–Aulacomyella neogeae* Zone (lower Tithonian). Locality MX-82-8 is 1.2 km (straight line) north-northeast of locality MX-80-20 where an ammonite submitted to Dr. R. W. Imlay (USGS, Washington, D.C.) for identification was tentatively identified as *Subneumayria profulgens* (Burckhardt, 1906) (Imlay, written commun., 1980). *Subneumayria* Spath, 1924, according to Arkell, Kummel, and Wright (1957, p. L327), is characteristic of the "*Idoceras* beds" in Mexico and, hence, occurs at a horizon equivalent to the *Idoceras* Zone of Cantu Chapa (1971). *Aulacomyella* also occurs at this locality in the same bed containing the ammonite specimen. Significantly, no specimens of *Mirifusus* are present at locality MX-82-3, which is situated 0.3 km north-northeast of locality MX-80-20 (see Locality Descriptions). In that the MX-82-8 horizon occurs above the MX-80-20/82-3 horizon in the Taman succession, it is at least slightly younger. Therefore, it is likely that the *Mirifusus*-bearing assemblage at locality MX-82-8 is either assignable to the upper part of the *Idoceras* Zone (= upper lower Kimmeridgian) or the lower part of the *Glochiceras* gr. *fialar* Zone (= lower upper Kimmeridgian) of Cantu Chapa (1971). The precise dating of the *Mirifusus* first occurrence event in east-central Mexico awaits further investigation by Pessagno and Longoria.

In summary, the North American evidence, though neither abundant nor absolute, suggests that *Mirifusus* Pessagno, 1977a, first occurs in Kimmeridgian strata that are equivalent to the lower part of the *Glochiceras* gr. *fialar* Zone or the *Idoceras* Zone of Cantu Chapa (1971). The lower part of the *G.* gr. *fialar* Zone is correlative with the *mutabilis* and *eudoxus* zones of Boreal northwestern Europe and with the *acanthicum* and *eudoxus* zones of the central and southern Tethys (Text-fig. 3). The *Idoceras* Zone is in turn correlative with the upper part of the *cymodoce* Zone of Boreal northwestern Europe and the *divisum* Zone of the European central and southern Tethys (Text-fig. 3). Hence, *Mirifusus* seems to make its first appearance either in the upper part of the lower Kimmeridgian or the lower part of the upper Kimmeridgian.

Other localities.—Data pertaining to the age of the *Mirifusus* first occurrence event were also presented by Baumgartner, DeWever, and Kocher (1980). *Mirifusus* Pessagno, 1977a, extends at least to the base of Biochronozone A of these workers. However, they stated that there are indications of an Oxfordian age for the upper part of Biochronozone A and offered supporting biostratigraphic data. Their most meaningful data come from the Romanian Carpathians and from DSDP Site 367 (Cape Verde Basin). Baumgartner, DeWever, and Kocher (1980, p. 45) admit that their data depend on assumptions and that an early Kimmeridgian age for Biochronozone A cannot be excluded.

Romanian Carpathians.—In the Romanian Carpathians Baumgartner, DeWever, and Kocher (1980) recovered *Mirifusus* from four of five samples from the "Jasper Beds." The Jasper Beds contain no fossils other than Radiolaria. As a result, their age can only be deduced by superposition. According to these workers the Jasper Beds overlie late Bathonian deposits with "*Belemnites*" *subhastatus* Quenstedt or early Callo-

vian nodular limestones with ammonite faunas belonging to the *macrocephalus* and *calloviense* Zones (Bancila, 1941; Patrulius, 1969). Baumgartner, De-Wever, and Kocher (1980, p. 29) state that "The Jasper Beds are in turn overlain by nodular and cherty limestone (Aptychus Beds) attributed to the late Oxfordian–early Kimmeridgian (Jekelius, 1920–21; Bancila, 1941; Turculet, 1971) based on the presence of ammonites and aptychi such as *Aspidoceras acanthicum* [Oppel, 1862–1863], *Sowerbyceras tortisulcatus* (d'Orbigny [, 1849]), *Streblites tenuilobatus* (Oppel [, 1862–1863]), *Taramelliceras* sp., *Hemihaploceras* sp., *Lamellaptychus lamellosus* (Parkinson [, 1811]), *L. sparsilamellosus* (Guembel [, 1861]), *L. rectecostatus* (Peters [, 1854]), etc. Hence, it can be stated that the Jasper Beds are no older than early Callovian and no younger than late Oxfordian." This list of megafossil taxa is hardly indicative of the upper Oxfordian. It is indicative rather of the lower and upper Kimmeridgian as defined herein (*cf.* Text-fig. 3 and discussion of data from DSDP Site 367, Cape Verde Basin). The assemblage cited above is more characteristic of the *Acanthicus* Beds in Romania (Neumayr, 1873; Herbich, 1878) and elsewhere in southern Europe (Arkell, 1956).

In the Hăghimas (Bicaz Gorge–Lacu Rosu area, Romanian Carpathians) Dragastan (1975, p. 124) stated that the *Acanthicus* Beds are 30 to 32 m thick. The lower 20 m are assigned in ascending order to the *platynota, hypselocyclum, uhlandi* (= *divisum* herein), *acanthicum,* and *beckeri* zones. Dragastan assigned the *platynota, hypselocyclum,* and *uhlandi* zones to the lower Kimmeridigian and the *acanthicum* and *beckeri* zones to the upper Kimmeridgian. The upper 10 m include the *lithographicum* and *ulmense* zones. According to Westermann and Zeiss (written commun., 1983) these latter two zones cannot be distinguished and are currently included in the *Gravesia* Zone or *hybonotum* Zone (lower Tithonian) of the central and southern Tethys (Text-fig. 3). Dragastan notes no upper Oxfordian ammonites in the *Acanthicus* Beds of the Hăghimas.

The Mesozoic strata in the Hăghimas Mountains (Bicaz Gorge area) are, according to Dragastan (1975, pp. 123, 124, fig. 1), included in two nappes, each displaying a different stratigraphic succession. The Jasper Beds (radiolarites) are included in the Bucovienne Nappe whereas the *Acanthicus* Beds are included in the Hăghimas Nappe. In the Bucovienne Nappe the Jasper Beds (radiolarites) and associated siliceous sandstones and shales overlie Middle Jurassic (Bajocian–Bathonian) limestones containing *Bositra buchii* (Roemer, 1836) and are in turn overlain unconformably either by the Beds of Lunca (Tithonian–Neocomian) with numerous aptychi or by Barremian to Albian wildflysch (Dragastan, 1975). In the Hăghimas Nappe it is difficult to understand how the Jasper Beds can be dated as strictly late Callovian to Oxfordian in that underlying strata are Bathonian (youngest possible age) and overlying strata (Beds of Lunca) are Tithonian to Neocomian.

The age of the Jasper Beds in the Romanian Carpathians must be examined through a window of complex structure and stratigraphy as well as differences of opinion pertaining to the ranges of fossils in overlying strata. Bancila (1941) studied the stratigraphy in the Hăghimas in the Ciuc Region immediately to the south of the Bicaz Gorge–Lacu Rosu area. According to Bancila (1941, p. 71) the Jasper Beds overlie fossiliferous Dogger sandstones and are in turn overlain by the *Acanthicus* Beds (Kimmeridgian). One suspects because of the proximity of this area to that studied by Dragastan (1975) that the contact between the Jasper Beds and the *Acanthicus* Beds in the Ciuc Region is a tectonic contact (see discussion above).

In the Rarău–Breaza area of the northeastern Romanian Carpathians the Jasper Beds are either overlain conformably by the Aptychus Beds (*e.g.,* between Moldova Valley and Valea Caselor) or unconformably by Lower Cretaceous strata (*e.g.,* wildflysch at Pecistea) (Turculet, 1971). Turculet (1971, fig. 5) divided the Aptychus Beds into a lower horizon (upper Oxfordian–lower Kimmeridgian) and an upper horizon (upper Kimmeridgian, Tithonian, Berriasian). In that Turculet appears to follow the older definition of the Kimmeridgian (Arkell, 1956; Gasiorowski, 1962, table 1) all of his lower Kimmeridgian equates with both the lower and upper Kimmeridgian as defined herein. Turculet (1971, pp. 32, 38) correlated his upper Aptychus horizon with Zones VI and VII of Gasiorowski. Gasiorowski equated the lowermost part of Zone VI with the *beckeri* Zone (= uppermost Kimmeridgian herein); the top of Zone VI corresponds to the top of the Tithonian whereas Zone VII corresponds to the Berriasian. Except for calpionellids in the upper Tithonian and Berriasian other fossils (*e.g.,* ammonites) are rare in the Aptychus Beds.

Turculet's assignment of the lower Aptychus horizon to the "upper Oxfordian–lower Kimmeridgian" is nebulous. It is not clear whether he meant to indicate that this horizon definitely included both upper Oxfordian and "lower" Kimmeridgian strata or that it included strata that might be placed anywhere in the upper Oxfordian to "lower" Kimmeridgian interval. The fact that Turculet made no attempt to correlate this interval with Gasiorowski's Zones IV and V appears to support the latter assumption.

Turculet's chronostratigraphic assignment of the lower Aptychus horizon is based primarily on the presence of three Aptychi (Turculet, 1971, pl. 42): *Lamellaptychus* grupa A, aff. *rectecostatus* (Peters, 1854) em. Trauth f. typ. Trauth, 1938; *Lamellaptychus,* grupa B, *sparsilamellosus* (Guembel, 1861) f. typ. Trauth, 1938; *Lamellaptychus* grupa B, *lamellosus* (Parkinson, 1811) em. Trauth f. typ. Trauth, 1938. A fourth species is listed. However, it is only known from Romania. The other three taxa also occur in Kimmeridgian, Tithonian, and Berriasian strata elsewhere in Europe (Turculet, 1971, pl. 42).

In our opinion the assignment of even a portion of the lower Aptychus horizon to the upper Oxfordian based on these long-ranging taxa would be tenuous. Gasiorowski (1962, p. 45) indicated that the base of his Zone IV (= *bimammatum* Zone; Text-fig. 3) is the moment of diversification among aptychi. Whereas Gasiorowski (1962, pp. 46–52) cited as many as 15 specific and (or) subspecific taxa from Zone IV in the western Carpathians, Swabian Alb, Friburg Alps, and other localities, Turculet cited only the four taxa noted above from the lower Aptychus horizon.

During the 14th European Micropaleontological Colloquium the senior author with the help of Dr. Paulian Dumitrica (Instit. Geol. and Geophys., Bucharest) collected eight samples from the radiolarites (Jasper Beds) exposed along the highway near Lacu Rosu. Sample RO-8A from near the base of the radiolarian chert exposure contains *Mirifusus guadalupensis* Pessagno, 1977a (fragment), *M. mediodilatata* (Rüst, 1885) (fragment), *Hsuum maxwelli* Pessagno, 1977a, *s.s., Acanthocircus variabilis* (Squinabol, 1914), *Tritrabs rhododactylus* Baumgartner, 1980a, and *Archaeospongoprunum imlayi* Pessagno, 1977a. The presence of *M. guadalupensis* definitely indicates that this sample is assignable to either Zone 2 (see emended definition herein) or to the lower part of Zone 3.

Although Baumgartner, DeWever, and Kocher (1980, table 1) did not note *Mirifusus* at their Lacu Rosu locality in the Hăghimas, they did record its presence in the Jasper Beds at localities in the Drocea Mountains and Rărau Mountains (eastern Carpathians). Unfortunately, their "blanket treatment" of the megafossil data is misleading.

Cape Verde Basin (DSDP Site 367).—As noted in Baumgartner, DeWever, and Kocher (1980), data pertaining to the integration of biostratigraphic data for radiolaria with those of other fossil groups are presented for Deep Sea Drilling Project [DSDP] Site 367 (Cape Verde Basin). Unfortunately, most of the data pertaining to the age of their Biochronozone A or the *Mirifusus* first occurrence event are hardly compelling. According to Baumgartner, DeWever, and Kocher (1980, table 1), *Mirifusus* occurs near the base of the sedimentary section in Core 37 (sect. 1; 147–149 cm). No megafossils were found at this horizon. However, benthonic foraminifera (Kuznetsova and Siebold, 1978) and dinocysts (Williams, 1978) were recorded in underlying Core 38. Kuznetsova and Siebold (1978, p. 522) assign the lower part of the section to the late Oxfordian based on the association of numerous Dentalinae, *Lenticulina quenstedti* (Guembel, 1862), *L. uhligi* (Wisniowski, 1890), *L. semiexpleta* (Schwager, 1865) and the "Spirillinae." Curiously, they stated (1978, p. 522) that the boundary between the Kimmeridgian and Oxfordian cannot be placed utilizing their foraminiferal assemblages.

Williams (1978, p. 783) on the basis of his study of the dinoflagellates, found diagnostic assemblages in Cores 38 and 35. He stated "The dinocysts include *Epiplospheara bireticulata* Klement [, 1960], *Prolixosphaeridium mixtispinosum* (Klement) Davey [, 1966], *Scriniocassis dictyotum* (Cookson and Eisenack) Beju [, 1971], *Sirmiodinium grossi* Alberti *sensu* Gitmez and Sarjeant, 1972, *Systematophora fasciculigera* Klement [, 1960], and *S. turonica* (Alberti) Downie and Sarjeant [, 1964] (figure 2). *E. bireticulata, P. mixtispinosum,* and *S. grossi sensu* Gitmez and Sarjeant are only known from the Kimmeridgian (Sarjeant, 1975)." Riley and Sarjeant (1972) indicate that *E. bireticulata* Klement, 1960, and *P. mixtispinosum* (Klement, 1960) range from the *cymodoce* Zone (= upper lower Kimmeridgian herein) to the *eudoxus* Zone (= middle upper Kimmeridgian herein) of Germany whereas the third species, *S. grossi* Alberti, 1961, *sensu* Gitmez and Sarjeant (1972), ranges from the *cymodoce* Zone to the *rotunda* Zone (= upper lower Tithonian herein) of England (Text-fig. 3). It should be noted that Williams (1978), Riley and Sarjeant (1972), and Sarjeant (1975) follow Arkell's (1956) definition of the Kimmeridgian. By this definition even the *rotunda* Zone would be included in the Kimmeridgian. Nevertheless, their data correspond well with those from North America.

Renz (1978) found numerous aptychi in Upper Jurassic strata at DSDP Site 367. In Core 36 (sect. 2, 72–73 cm) he recorded *Laevaptychus mexicanus* (Castillo and Aguillera, 1895). Castillo and Aguillera (1895, p. 45) originally described this taxon from Upper Jurassic strata in the Sierra Catorce, San Luis Potosi, Mexico, but did not cite its stratigraphic position. Renz assumed that Core 36 is of late Oxfordian age because of its position below Core 35, sections 4 and 5 where the aptychi are supposedly also late Oxfordian. However, it should be noted that detailed studies of the Upper

Jurassic stratigraphy and ammonite faunas of the Sierra Catorce by Verma and Westermann (1973, pp. 107–320) indicate that the oldest fossiliferous strata are Kimmeridgian in age and are included in the El Pastor Member of the La Caja Formation. Verma and Westermann record *Idoceras* sp. cf. *I. inflatum* Burckhardt, 1906, *I.* sp. cf. *I. mutabilis* Burckhardt, 1912, and *I.* ex gr. *I. neohispanicum* Burckhardt, 1912, from 3 m (9.8 ft) above the base of the El Pastor Member. These ammonites are clearly assignable to the *Idoceras* Zone (Cantu Chapa, 1971; Imlay, 1980) and are indicative of late early Kimmeridgian (= upper part of *cymodoce* Zone of northwest Europe; *cf.* Text-fig. 3). Renz (1978, p. 502) recorded the following taxa from Core 35 (sects. 4 and 5): *Lamellaptychus* sp. cf. *L. thoro* (Oppel, 1863), *L.* (?) *lithographicus* (Oppel, 1863), *L.* sp. cf. *L. crassicauda* (Quenstedt, 1846–49), *L. sparcilamellosus* (Guembel, 1861), *L. mucrocostatus* Trauth, 1938, and *Laevaptychus latus seriporus* Trauth, 1931. Most of these aptychi, according to Renz, occur in both the Oxfordian and Kimmeridgian; some, such as *L. mucrocostatus* and *L. thoro,* are also known from the Tithonian. Renz indicated that one species, *L. sparcilamellosus,* is only known from the upper Oxfordian. However, Turculet (1971, pl. 42) showed this taxon to also occur in the Kimmeridgian and Tithonian. Finally, from overlying Core 34 (sect. 4) Renz recorded *Punctaptychus punctatus* (Volz, 1837), *Granulaptychus planulati* (Quenstedt, 1858), *Lamellaptychus pleiadensis* Trauth, 1938, and *L. latus vermiporus* Trauth, 1931. Of these aptychi, *G. planulati* is the most significant. According to Renz (1978, p. 503) this aptychus "has repeatedly been observed within the body chambers of Perisphinctidae, especially of *Lithacoceras ulmensis* (Oppel, 1858)." Ziegler (1971, p. 65, fig. 22) indicated that *Lithacoceras ulmensis* (Oppel, 1858) ranges from the upper part of the *beckeri* Zone to the top of the *Gravesia* Zone in southwestern Germany (uppermost Kimmeridgian to lowermost Tithonian) (Text-fig. 3). Renz, in part following the earlier definition of the Kimmeridgian (*e.g.,* Arkell, 1956) assigned this core interval to the lower Kimmeridgian.

Summary.—

(1) Data from California and elsewhere in western North America indicate that *Mirifusus* Pessagno, 1977a, occurs in upper Kimmeridgian strata that are correlative with the *eudoxus* and the *mutabilis* zones of northwestern Europe (Text-fig. 3).

(2) In east-central Mexico, *Mirifusus* first occurs in the lower more massively-bedded part of the Taman Formation at a horizon (loc. MX-82-8) that is above the first occurrence of the pectenacid *Aulacomyella* (Furlani, 1910) and somewhat above strata containing an ammonite that is characteristic of the *Idoceras* beds in Mexico (= *Idoceras* Zone of Cantu Chapa, 1971). Based on the range of *Aulacomyella* and the presence of this ammonite, it can be established, therefore, that *Mirifusus* makes its first appearance in strata that are no older than the *Idoceras* Zone (late early Kimmeridgian). It is likely that this horizon is no younger than the lower part of the *Glochiceras* gr. *fialar* Zone (late Kimmeridigian) of Cantu Chapa (1971). An assignment of the MX-82-8 horizon to this latter zonal unit is further reinforced by the fact that it appears to occur more or less along strike with a locality near La Cuesta where Burckhardt (*in* Heim, 1926) identified *Glochiceras fialar* (Oppel, 1858) and other ammonites characteristic of the *G.* gr. *fialar* Zone of Cantu Chapa (1971). The *Idoceras* and *G.* gr. *fialar* Zones of the Mexican Tethys are correlative with the *divisum, acanthicum,* and *eudoxus* zones of the European Tethys (Text-fig. 3).

(3) In the Romanian Carpathians, *Mirifusus* Pessagno, 1977a, occurs near the base of the Jasper Beds in the Hăghimas Nappe succession (Bicaz Gorge–Lacu Rosu area). It also was noted by Baumgartner, DeWever, and Kocher (1980) in the Jasper Beds in the Rarău and Drocea Mountains (eastern Carpathians). Unfortunately, the age of the Jasper Beds can only be deduced by superposition; they overlie strata of Bathonian or early Callovian age and underlie aptychus-bearing strata whose precise age is controversial. In the Rarău Mountains, Turculet (1971) indicated that the lower Aptychus horizon included strata of both late Oxfordian and early Kimmeridgian age. Curiously, all of the taxa he utilized to support this determination also occur in the Kimmeridgian, Tithonian, and Berriasian. Hence, a Kimmeridgian age for the Jasper Beds cannot be excluded.

(4) Data from DSDP Site 367 (Cape Verde Basin) derived from studies of benthonic foraminifera, aptychi, and dinoflagellates are contradictory and controversial. Baumgartner, DeWever, and Kocher (1980) established that *Mirifusus* occurs near the bottom of the section in Core 37. Renz (1978) maintained that the interval from Core 36 (sect. 2: 72–73 cm) to Core 35 (sect. 4: 147–148 cm) is upper Oxfordian in spite of the fact that the majority of his aptychi occur in both the Oxfordian and Kimmeridgian. One aptychus, *Laevaptychus mexicanus* (Castillo and Aguillera, 1895) from Core 36, was originally described from Mexico in strata that cannot be older than the *Idoceras* Zone (latest early Kimmeridgian). The presence of *Granulaptychus planulati* (Quenstedt, 1858), which has been elsewhere observed to be associated with the body chamber of *Lithacoceras ulmensis* (Oppel, 1858),

indicates an equivalence of Core 34 (sect. 4) to the upper part of the *beckeri* Zone and all of the overlying *Gravesia* Zone (= uppermost Kimmeridgian to lowermost Tithonian). Kuznetsova and Siebold (1978) assigned the interval from Core 38 to Core 35 to the upper Oxfordian on the basis of their studies of the benthonic foraminiferal assemblage. However, they admitted they could not place the boundary between the Oxfordian and Kimmeridgian on the basis of their investigation. Williams (1978) found a diagnostic dinoflagellate assemblage in Core 38 (bottom of sedimentary section) and in Core 35 and assigned this interval to the Kimmeridgian. Significantly, three species, *Epiplosphaera bireticulata* Klement, 1960, *Prolixosphaeridium mixtispinosum* Klement, 1960, and *Siriodinium grossi* Alberti, 1961 *sensu* Gitmetz and Sarjeant, 1972, make their first appearance in the *cymodoce* Zone (= upper lower Kimmeridgian) of Germany and England. Two species, *E. bireticulata* and *P. mixtispinosum,* range no higher than the *eudoxus* Zone (middle upper Kimmeridgian; see Text-fig. 3).

Parvicingula first occurrence event (base of Zone 1)

The first occurrence of *Parvicingula* Pessagno, 1977a, occurs at a time of major change in the Mesozoic radiolarian assemblage. Immediately below this horizon a number of taxa (*e.g., Canutus* Pessagno and Whalen, 1982, *s.s., Canoptum anulatum* Pessagno and Poisson, 1981, and so forth) make their final appearance whereas at this horizon *Parvicingula* Pessagno, 1977a, *Perispyridium* Dumitrica, 1978, *Higumastra* Baumgartner, 1980a, *Emiluvia* Foreman, 1973, and other taxa suddenly appear. The magnitude of this faunal break is at least as great as that occurring between the Upper Triassic and Lower Jurassic and ranks as one of the most catastrophic changes in the Mesozoic radiolarian assemblage.

In east-central Oregon (John Day Inlier) *Parvicingula* Pessagno, 1977a, first occurs in the Warm Springs Member of the Snowshoe Formation (Lupher, 1941; Dickinson and Vigrass, 1965). The Warm Springs Member (Lupher, 1941; Smith, 1980) contains a continuous succession of strata ranging in age from Early Jurassic (latest Toarcian) to Middle Jurassic (Aalenian, early Bajocian). Ammonite faunas from these strata have been described by Imlay (1968, 1973). Imlay (1968, 1973, 1980), as well as Pessagno and Blome (1980) and Pessagno and Whalen (1982), assigned what most workers now call Aalenian to the lower Bajocian (see Westermann, 1979). The Aalenian is now regarded as a valid stage that marks the base of the Middle Jurassic. Radiolaria associated with latest Toarcian ammonite faunas are correlated with the *levesquei* Zone of northwestern Europe, lack *Parvicingula,* and are assigned to radiolarian Zone 01 (Pessagno, Blome, Whalen, and Cheng, in prep.). Radiolarian faunas closely associated with the Aalenian ammonite *Tmetoceras scissum* (Benecke, 1865) contain *Parvicingula* and *Perispyridium* Dumitrica, 1978, and are definitely assignable to radiolarian Zone 1.

PROBLEMS OF CORRELATION

Baumgartner, DeWever, and Kocher (1980) used a computerized treatment of radiolarian biostratigraphic data to compile their zonal scheme. The utilization of a technique such as that of Guex (1979) is undoubtedly quite valuable in sorting out biostratigraphic data and subsequently developing a means of correlation. However, such computerized techniques are still dependent on biostratigraphic data derived from paleontological observations. If poor judgment is used by a paleontologist in identifying existing taxa or defining new taxa, errors in correlation will result no matter how sophisticated the technique.

As noted elsewhere in this report, we admit that many of the taxa cited by Pessagno (1977a) in his definition of Upper Jurassic zonal units are longer ranging than previously believed. This soon became evident from our own work as well as that of Baumgartner, DeWever, and Kocher (1980). Detailed studies in progress in California (Pessagno and Blome, in prep.), Baja California Sur (Davila, in prep.), and east-central Mexico (Pessagno and Longoria, in prep.) should eventually define the range zones of those taxa described by Pessagno (1977a, 1977b), but not utilized in the present report. Many differences in ranges of taxa cited by Baumgartner, DeWever, and Kocher represent differences in taxonomy, often coupled with paleo-oceanographic and preservational factors.

Taxonomic Problems Affecting Correlation

Baumgartner, DeWever, and Kocher (1980) claimed that *Syringocapsa rotunda* (Hinde, 1902) [= *Obesacapsula rotunda* (Hinde), Pessagno, 1977b (part)] occurs in the upper Tithonian. Although the specimen figured from the Berriasian by Baumgartner, DeWever, and Kocher (1980, pl. 3, fig. 12) is most certainly *O. rotunda s.s.,* we have not observed this morphotype in either the upper Tithonian of California, Baja California Sur, or east-central Mexico. We suspect that Baumgartner, DeWever, and Kocher included the form referred to herein as *O.* sp. aff. *O. rotunda* under *O. rotunda* (Pl. 4, fig. 9). *O.* sp. aff. *O. rotunda* is closely related to and most likely ancestral to *O. rotunda.* In

California it has been observed in the lower part of Zone 3 at loc. NSF-908 and in the lower part of Zone 4 at loc. SA-43B (see Locality Descriptions). In Baja California Sur this form occurs at loc. BJV-20 in a sample also containing common *Buchia piochii* (Gabb, 1869) (middle to upper Zone 4; upper Tithonian).

As far as can be determined from data from the Western Hemisphere, *O. rotunda s.s.* makes its first appearance in the Berriasian, as emphasized by Pessagno (1977b). It is difficult to determine at the present time whether the difference in range of *O. rotunda* is due to a much broader taxonomic concept on the part of Baumgartner, DeWever, and Kocher, or is due to paleo-oceanographic or preservational determinants. Until this problem is studied in more detail, we will de-emphasize the importance of *O. rotunda* in defining the base of Zone 5.

Baumgartner, DeWever, and Kocher included a variety of morphotypes under *Parvicingula boesii* (Parona, 1890) [= *Ristola boesii* (Parona, 1890)]. Their figured form is considerably different in shape from Parona's (pl. 6, fig. 9) type specimen; it is much more pointed apically, less spindle-shaped, and possesses more weakly developed circumferential ridges. As far as can be determined, no specimens corresponding precisely to Parona's type specimen have been figured in recent literature (see Systematic Paleontology).

Napora lospensis Pessagno of Baumgartner, DeWever, and Kocher bears no resemblance to *N. lospensis* Pessagno, 1977a. It possesses a longer, slender, structurally different horn; longer, less massive feet; and much less massive pore frames.

The inclusion of *Mirifusus baileyi* Pessagno, 1977a, by Baumgartner, DeWever, and Kocher in *M. mediodilatata* (Rüst, 1885) serves no purpose other than to obscure important biostratigraphic and phylogenetic relationships (see Systematic Paleontology and emended definition of Zone 3).

PALEOLATITUDINAL/PALEOCLIMATIC CONSIDERATIONS

The Upper Jurassic faunas reported by Baumgartner, DeWever, and Kocher (1980) from the Mediterranean area, by Tippit (1981) from Oman, and from numerous DSDP sites (*e.g.,* Foreman, 1973, 1975; Moore, 1973) are representative of the Central Tethys. These faunas are characterized by the presence of *Ristola* Pessagno and Whalen, 1982, and by the absence of *Parvicingula* Pessagno, 1977a (*sensu* Pessagno and Whalen, 1982). On the other hand, the Tethyan faunas of the Taman and Pimienta formations of east-central Mexico are characteristic of the Northern Tethys and possess elements in common with both the Boreal faunas of California and those of the Central Tethys. Whereas *Parvicingula* is absent in the Central Tethyan *Ristola* assemblage, it is quite common in the Northern Tethyan assemblage of eastern Mexico and occurs in Boreal strata as far north as Alaska (*e.g.,* Brooks Range). The presence of microfossils such as calpionellids and megafossils such as *Aulacomyella* Furlani, 1910, *Microacanthoceras* Spath, 1925, and *Mazapilites* Burckhardt, 1919, substantiates the Tethyan character of Upper Jurassic radiolarian assemblages of eastern Mexico. The central and northern Tethyan radiolarian assemblages differ from those of the Boreal Realm by being more diversified. The Pantanellidae Pessagno, 1977b (*sensu* Pessagno and Blome, 1980), possess four or five times the number of species level taxa (named and unnamed) in Tethyan faunas that they do in faunas from the southern part of the Boreal Realm. Our studies to date indicate that pantanellids are virtually absent at higher Boreal latitudes.

In summary, these simple but yet important differences in radiolarian faunal composition allow us to separate the Tethyan Realm into a Central Tethyan Province characterized by *Ristola* Pessagno and Whalen, 1982, and high pantanellid diversity and a Northern Tethyan Province characterized by the presence of *Parvicingula* Pessagno, 1977a, and high pantanellid diversity. Faunas from the southern portion of the Boreal Realm are characterized by the presence of *Parvicingula* and by a dramatic drop in pantanellid diversity; pantanellids are apparently lacking in high latitude Boreal Middle and Upper Jurassic strata.

DISPLACED TERRANES AND THEIR EFFECT ON BIOSTRATIGRAPHIC CORRELATION

Most geologists now recognize that much of the western part of the Cordilleran region is a collage of displaced terranes that were accreted to the margin of the North American craton during Paleozoic and Mesozoic times. The brilliant discovery of the first of these, the Wrangellian terrane, by Jones, Silberling, and Hillhouse (1977), revolutionized geological thinking pertaining to the North American cordillera and indeed to the evolution of the entire Circum-Pacific margin. Many terranes (*e.g.,* Wrangellia) originated at near equatorial latitudes and have been displaced northward hundreds or even thousands of kilometers from their point of origin.

It is now apparent from our studies of the radiolarian fauna and from paleomagnetic investigations that the Coast Range ophiolite and its cover of volcanogenic-pelagic strata originated at near equatorial latitudes and was displaced northward during the course of Middle Jurassic and Late Jurassic times. Paleomagnetic

data from the Stanley Mountain remnant of the Coast Range ophiolite at Alamo Canyon (locs. SA-4 through SA-43B herein) indicate that these ophiolitic rocks originated 14° ± 7° north or south of the Jurassic paleoequator (see McWilliams and Howell, 1982). Similar results (unpublished) have been obtained from the Coast Range ophiolite at Point Sal (Hopson, oral commun., 1983).

Investigations of the radiolarian assemblage by Pessagno and Blome (in prep.) agree well with the available paleomagnetic data. For example, at Stanley Mountain, the lower 72 m (238 ft) of the succession above the ophiolite contain the Central Tethyan *Ristola* Pessagno and Whalen, 1982, assemblage (Zone 2 to Zone 3). A sample from 73 m (239 ft) contains the first *Parvicingula* Pessagno, 1977a, and poorly preserved pantanellids; this sample may be either representative of the Northern Tethyan Province or the Southern Boreal Province. The interval from 79.5 m (261 ft) to 106.4 m (330 ft) contains a Southern Boreal assemblage with *Parvicingula* and poorly diversified pantanellids. The same changes in the radiolarian assemblage have been observed at Point Sal, Cuesta Ridge, Llanada, and at other localities where remnants of the Coast Range ophiolite are exposed.

It is now also apparent that the Middle and Upper Jurassic red, manganiferous ribbon cherts of the Franciscan Complex contain a Tethyan (predominantly Central Tethyan) radiolarian assemblage. Cherts of this sort, bearing Tethyan radiolarian faunas, are inherent to subduction complexes (melange belts) from California to Alaska (*e.g.,* Otter Point complex, western Oregon; Pacific Rim complex, British Columbia).

Obviously, paleolatitudinal changes due to displaced terranes make it difficult to establish the ranges of many radiolarian taxa. At Stanley Mountain, for instance, one might conclude that *Parvicingula* Pessagno, 1977a (*sensu* Pessagno and Whalen, 1982), does not range below Zone 3 (lower Tithonian). Yet it can be established from the investigations of Pessagno and Whalen (1982) that this taxon in east-central Oregon first appears at the base of Zone 1 (Middle Jurassic: Aalenian). Fortunately, a large number of radiolarian taxa occur in both the Tethyan and Boreal faunal realms. As a result, it is possible to correlate Central Tethyan faunas of Baumgartner, DeWever, and Kocher (1980) with those of Boreal North America. The Northern Tethyan assemblage of eastern Mexico provides an important link in these correlations.

Comments on the Ranges of Selected Taxa

Ristola procera (Pessagno, 1977a) has a longer range in the California Coast Ranges than it does in the Central Tethys of southern Europe. This difference in range may be paleolatitudinally controlled. *R. procera* ranges to the top of the upper Tithonian (*Buchia* sp. aff. *B. okensis* Zone) in the Boreal strata of the Great Valley sequence. In southern Europe *R. procera* ranges no higher than the lower Tithonian.

We agree that *Acanthocircus dicranocanthos* (Squinabol, 1914) ranges below the base of the Berriasian. Tippit (1981) found this taxon associated with "*E.*" *ptyctum* Riedel and Sanfilippo, 1974, *Sethocapsa cetia* Foreman, 1973 (*sensu* Baumgartner, DeWever, and Kocher, 1980), and *Ristola altissima* (Rüst, 1885) in the Halfa Formation of Oman. In addition, we have recently encountered *A. dicranocanthos* in strata assignable to the lower part of Zone 4 in the Taman Formation of east-central Mexico (loc. MX-82-37; see p. 10 and Locality Descriptions). *A. dicranocanthos* is strictly a Tethyan species. In California it occurs only in the red, manganiferous cherts of the Franciscan Complex and has never been observed in the Boreal strata of the Great Valley sequence or in underlying pelagic Boreal strata below the Great Valley sequence.

Parvicingula(?) *cretacea* Baumgartner, 1980b (*in* Baumgartner, DeWever, and Kocher, 1980; = *Ristola cretacea* Baumgartner, 1980b), though distinctive, appears to be a provincial southern European species. It has not been observed in Tethyan samples from Indonesia, Oman, or elsewhere. Baumgartner, DeWever, and Kocher (table 1) noted this form in two samples from Romania and in one from Italy.

Andromeda violae Baumgartner, 1980b (*in* Baumgartner, DeWever, and Kocher, 1980, table 3b) is said not to range above the top of "Biochronozone" B (top of unitary association 5). The top of "Biochronozone" B corresponds to the final occurrence of *Mirifusus guadalupensis* Pessagno, 1977a. In the California Coast Ranges we have observed *A. violae* in the lower portion of Zone 4 at locality SA-43B (Alamo Canyon; see Locality Descriptions). Whether the longer range of this taxon in California is due to paleo-oceanographic, paleogeographic, preservational, or observational factors is unknown.

CORRELATION OF ZONAL SCHEMES

Text-figure 3 is an attempt to correlate the emended zonation proposed herein with that of Baumgartner, DeWever, and Kocher (1980). Although there are major differences between the faunal assemblages as noted above, a sufficient number of taxa occur in common to allow the correlation of some zonal units.

The base of "Biochronozone" A of Baumgartner, DeWever, and Kocher (1980) corresponds approximately to the base of Zone 2 as redefined herein. The top of

"Biochronozone" B, due to the final occurrence of *Mirifusus guadalupensis* Pessagno, 1977a, corresponds to the lower part of Zone 3 as redefined herein. Possible points of linkage within "Biochronozone" C appear to be the final occurrence of "*Eucyrtidium*" *ptyctum* within the middle part of Zone 4 (upper Tithonian strata with *Buchia piochii* (Gabb, 1869), Baja California Sur) and the first occurrence of *Acanthocircus dicranocanthos* Squinabol, 1914, within the lower part of Zone 4 in east-central Mexico (lower Tithonian part of Taman Formation at loc. MX-82-37; see p. 10 and Locality Descriptions).

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SYSTEMATIC PALEONTOLOGY

INTRODUCTION

The concept of the morphospecies varies greatly among radiolarian specialists. This, to a large degree, depends on whether one is a Cenozoic or a Mesozoic specialist and furthermore, it appears to be related to the mode of illustrating and studying radiolarian taxa. Most Cenozoic Radiolaria have tests comprised of opaline silica. When specimens are properly cleaned, their internal and external features are readily discernible and can be easily illustrated using transmitted light optics. Few, if any, Mesozoic Radiolaria have tests comprised of opaline silica. Their tests, instead, have been replaced by quartz, chalcedony, smectite, pyrite, limonite, and calcite. Even specimens whose tests are still siliceous are often difficult to photograph with transmitted light optics simply because test walls are not sufficiently hyaline.

Whereas transmitted light optics are still the primary tool of the Cenozoic specialist, the scanning electron microscope by necessity has become the primary tool of the Mesozoic specialist. Because the scanning electron microscope is capable of recording the minutest details of radiolarian morphology, students of Mesozoic Radiolaria are presented with a wealth of morphological data. Taxa are therefore described in more detail than would be normal utilizing transmitted light optics. As a result, Cenozoic specialists tend to be regarded by Mesozoic specialists as ultra "lumpers" and most Mesozoic specialists are regarded by Cenozoic specialists as ultra "splitters." In spite of such differences in approach, radiolarian workers agree that the classification presented by Haeckel (1887) is artificial in character and needs to be replaced by a more phylogenetic classification (*cf.* Riedel, 1971; Pessagno, 1977c). Haeckel's detailed classification was based to a large degree on the geometry or shape of the radiolarian test. Pessagno (1977c, p. 928) stated "It is clear that if one hopes to construct a more phylogenetic classification of Mesozoic or for that matter Cainozoic Radiolaria, one must consider *how* a radiolarian test is constructed. This is particularly true at the supergeneric level." This thesis is well illustrated in the recent literature (*e.g.,* Pessagno, 1973; Pessagno and Blome, 1980; Baumgartner, 1980a; Pessagno and Whalen, 1982).

In routine stratigraphic investigations of Mesozoic Radiolaria the majority of specimens can be identified using a good quality stereoscopic microscope with magnifications ranging from 100× to 250×. Diagnostic features recognized from scanning electron micrographs can usually be recognized with a stereoscopic microscope.

In the systematic paleontology section to follow, the designation USNM indicates that a type specimen has been deposited at the U.S. National Museum, Washington, DC. All USNM types have been assigned catalogue numbers. Holotypes are isolated on one hole cardboard slides bearing a USNM catalogue number; paratypes deposited at the U.S. National Museum are mounted on glass slides also bearing a USNM catalogue number. Paratypes deposited in the Pessagno Collection are isolated on one hole cardboard slides.

All new taxa described in this report are illustrated by means of scanning electron micrographs. Where preservation permits, transmitted light photomicrographs are also utilized.

Measurements are made with an ocular micrometer in either a stereoscopic microscope or a transmitted light microscope. No measurements are made from scales on the scanning electron micrographs. All measurements are given in μm.

Finally, it should be noted that the authorship of all new radiolarian taxa is assigned to Pessagno and Blome.

Order **POLYCYSTIDA** Ehrenberg, 1838

Suborder **SPUMELLARIINA** Ehrenberg, 1838

Superfamily **SPONGODISCACEA** Haeckel, 1881 (emend. Pessagno, 1971, 1973)

Subsuperfamily **PSEUDOAULOPHACILAE** Riedel, 1971 (emend. Pessagno, 1971)

Family **ORBICULIFORMIDAE** Pessagno, 1973

Type genus.—*Orbiculiforma* Pessagno, 1973.

Range and occurrence.—Triassic to Cretaceous; Boreal, Tethyan, and Austral realms.

Genus **ORBICULIFORMA** Pessagno, 1973

Type species.—*Orbiculiforma quadrata* Pessagno, 1973.

Range and occurrence.—Same as for family.

Orbiculiforma lowreyensis Pessagno
Plate 1, figures 9–11

Orbiculiforma lowreyensis Pessagno, 1977a, p. 74, pl. 3, figs. 15, 16; pl. 4, figs. 1–3.

Range.—Zone 4 (upper Tithonian) to Zone 5, Subzone 5A (Berriasian).

Occurrence.—California Coast Ranges, Baja California Sur. *O. lowreyensis* is quite abundant in the California Coast Ranges in upper Tithonian strata assignable to the *Buchia piochii* Zone (Jones, Bailey, and Imlay, 1969). It is also common in strata assignable to the *Buchia piochii* Zone in Baja California Sur. Very rare specimens of *O. lowreyensis* were also observed at loc. NSF-810 (*Buchia uncitoides* Zone; Berriasian; see Locality Descriptions).

Superfamily **LIOSPHAERACEA** Haeckel, 1881 (emend. herein)

Description.—Spumellariina with a latticed, solid cortical shell; medullary shells when present, solid, latticed.

Remarks.—This superfamily is subdivided herein into the Entactiniilae Riedel, 1967, and the Liosphaerilae Haeckel, 1881. The Entactiniilae include all Liosphaeracea possessing an array of internal spicules that extend to, and often beyond the wall of the cortical shell; the Liosphaerilae lack internal spicules. The Entactiniilae first appeared in the Early Paleozoic and greatly declined at the end of the Early Jurassic. A lineage of Entactiniilae most likely gave rise to the Liosphaerilae during Triassic times.

Pessagno (1977a, p. 75) used the Sphaerellacea Haeckel, 1881, as a superfamily name. Haeckel (1881) originally treated as an order what Pessagno (1977a) called "Sphaerellacea" (*i.e.*, the Order Sphaerellaria). In that Haeckel's name is not based on any known family, it cannot be used as a superfamily name.

Subsuperfamily **LIOSPHAERILAE** Haeckel, 1881

Range and occurrence.—Triassic to Holocene. World-wide.

Family **PANTANELLIDAE** Pessagno, 1977b (emend. Pessagno and Blome, 1980)

Type genus.—*Pantanellium* Pessagno, 1977a.

Range and occurrence.—Upper Triassic to Lower Cretaceous. World-wide.

Genus **VALLUPUS** Pessagno and Blome, new genus

Etymology.—*Vallupus* (masc.) is a name formed by an arbitrary combination of letters (ICZN, 1964, Appendix D, pt. VI, Recommendation 40, p. 113).

Type species.—*Vallupus hopsoni* Pessagno and Blome, n. sp.

Description.—Test consisting of a cortical shell and a single medullary shell. Cortical shell elongate, helmet-like with symmetrical polygonal pore frames and a prominent imperforate, cylindrical collar (Pl. 1, figs. 19, 21) having a circular aperture. Single medullary shell spherical with small symmetrical polygonal pore frames; pore frames of medullary shell connected to pore frames of cortical shell by triradiate (axial section) radial beams; triradiate radial beams joining both cortical shell and medullary shell at sites of triple junctions

formed by adjoining pore frames. Cylindrical collar lacking radial beams.

Remarks.—This bizarre, Nassellarian-like form differs from all other Spumellarians in the Mesozoic by possessing an imperforate, cylindrical collar. Ongoing studies of the Upper Jurassic radiolarian assemblage of east-central Mexico by Pessagno and Longoria indicate that *Vallupus* definitely evolved from *Pantanellium* Pessagno, 1977a (*Pantanellium* sp. to unnamed intermediate to *Vallupus* sp.). Intermediate forms possessing two well-developed polar spines as well as a cortical shell with a cylindrical collar structure, have been observed at six horizons within the upper Kimmeridgian and lower Tithonian portions of the Taman Formation.

Range.—Upper Jurassic: Tithonian.

Occurrence.—California Coast Ranges, east-central Mexico, Costa Rica. According to Baumgartner (oral commun., 1980) this taxon is also present in his southern European faunas.

Vallupus hopsoni Pessagno and Blome, new species
Plate 1, figures 14–16, 18, 19, 21; Plate 5, figure 1

Etymology.—This species is named for Dr. C. A. Hopson (Univ. of Calif., Santa Barbara) in honor of his contributions to the geology of the California Coast Ranges.

Description.—Test small with very thick-walled cortical shell and thin-walled first medullary shell. Cortical shell with mixture of massive pentagonal and hexagonal pore frames lacking nodes at vertices; pore frames about two times thicker in Z direction than in Y direction (terminology: *cf.* Pessagno and Blome, 1980, text-fig. 5) tending to become elongate at junction with collar (Pl. 1, figs. 19, 21). Secondary radial beams with three broad longitudinal grooves alternating with three narrow longitudinal ridges. First medullary shell with fragile pentagonal and hexagonal pore frames.

Remarks.—*V. hopsoni,* n. sp., differs from all other Pantanellid species by possessing a cylindrical collar with a circular aperture and by lacking primary spines (polar spines).

Measurements (in μm).—Ten specimens (holotype plus nine paratypes).

	length of collar	width of collar	diameter of latticed cortical shell
Holotype (USNM 340255)	37.5	75	75
Mean	42.5	76	71.5
Maximum	75	100	80
Minimum	25	60	50

Type locality.—SA-43B. See Locality Descriptions.

Deposition of types.—Holotype: USNM 340255. Paratypes: USNM 340256 and Pessagno Collection.

Range.—Lower part of Zone 4 so far as known; upper Tithonian.

Occurrence.—Stanley Mountain remnant of Coast Range ophiolite in volcanogenic-pelagic strata overlying ophiolite. Locs. SA-39, SA-40, SA-43B at Alamo Creek. Upper part of Taman Formation at loc. MX-82-37. See Locality Descriptions.

Vallupus species A
Plate 1, figure 20

Range and occurrence.—Lower part of Zone 4 at loc. SA-43B; upper Tithonian.

Family **PRAECONOCARYOMMIDAE** Pessagno, 1976

Type genus.—*Praeconocaryomma* Pessagno, 1976.

Range.—Lower Jurassic (Pliensbachian) to Upper Cretaceous (Campanian).

Occurrence.—Boreal and Tethyan realms.

Genus **PRAECONOCARYOMMA** Pessagno, 1976

Conocaryomma Lipman. Empson-Morin, 1981 (part) [not *Conocaryomma* Lipman, 1969].

Type species.—*Praeconocaryomma universa* Pessagno, 1976.

Remarks.—Pessagno (1976) differentiated *Praeconocaryomma* from *Conocaryomma* on the basis of the number of medullary shells. *Praeconocaryomma* consistently possesses three medullary shells whereas *Conocaryomma* possesses four(?) or five medullary shells. There appears to be no direct phylogenetic link between these two superficially similar genera. *Praeconocaryomma* becomes extinct in the middle Campanian whereas *Conocaryomma* is only known from the middle and upper Eocene (Pessagno, 1976; Lipman, 1969).

Empson-Morin (1981) regarded *Praeconocaryomma* as a junior synonym of *Conocaryomma.* She stated (p. 260): "Since the medullary shell(s) represent growth stages which almost certainly can show some variation and comprise the immature portion of the skeleton, their taxonomic significance at the generic level is questionable." We believe, however, that test construction should be the primary criterion for developing a meaningful and more phylogenetic classification of Radiolaria. We agree that the features of the cortical shell are the most important criteria for differentiating species. Nevertheless, we regard the construction of the entire test to be the most important criterion for defining genera, families, and superfamilies. The number of medullary shells governs the manner in which

the test as a whole is constructed. This appears to be a consistent feature among families that we have studied in detail. For example, specimens in the Pantanellidae Pessagno, 1977b (see Pessagno and Blome, 1980) always possess a single medullary shell throughout their lengthy geologic history (Late Triassic to Early Cretaceous). Similarly, the Praeconocaryommidae always possess three medullary shells during their tenure from Early Jurassic (late Pliensbachian) to Late Cretaceous (middle Campanian) times.

Range.—Lower Jurassic (upper Pliensbachian) to Upper Cretaceous (middle Campanian).

Occurrence.—World-wide in Boreal and Tethyan realms.

Praeconocaryomma immodica
Pessagno and Poisson, 1981
Plate 1, figures 22–24

Praeconocaryomma magnimamma (Rüst, 1885). Pessagno, 1977a, p. 77, pl. 5, figs. 14–16; pl. 6, fig. 1.
Praeconocaryomma immodica Pessagno and Poisson, 1981, p. 57, pl. 7, figs. 2–9.

Range.—Upper Zone 1 (undifferentiated) to lower Zone 2; Kimmeridgian. Pessagno and Poisson (1981) originally believed that this species ranged down into the Lower Jurassic (upper Toarcian). These data were derived from a sample from the Klamath Mountains of California; however, a reanalysis of the fauna from this sample indicates that the specimen thought to be *P. immodica* represents a related but unnamed form.

Occurrence.—World-wide in Tethyan Realm and southern part of Boreal. See Pessagno (1977a).

Suborder **NASSELLARIINA** Ehrenberg, 1875

Family **EPTINGIIDAE** Dumitrica, 1978

Type genus.—*Eptingium* Dumitrica, 1978.

Range and occurrence.—Triassic to Upper Jurassic; world-wide in Boreal and Tethyan realms.

Genus **PERISPYRIDIUM** Dumitrica, 1978

Type species.—*Trilonche*(?) *ordinaria* Pessagno, 1977a.

Range.—Base of Zone 1 to lower part of Zone 4; Aalenian to upper Tithonian.

Occurrence.—Same as for family.

Perispyridium ordinarium (Pessagno)
(emend. Pessagno and Blome, 1982)
Plate 1, figure 7

Trilonche(?) *ordinarium* Pessagno, 1977a, p. 79, pl. 6, fig. 14.
not *Perispyridium ordinarium* (Pessagno). Dumitrica, 1978, pp. 35, 36, pl. 3, figs. 1, 2, 5; pl. 4, fig. 9.
Perispyridium ordinarium (Pessagno). Pessagno and Blome, 1982, p. 294, pl. 6, figs. 4, 12, 15.

Range.—Zone 2 to lower part of Zone 4; Kimmeridgian to upper Tithonian (see Text-figs. 1, 3).

Occurrence.—Tethyan Realm and southern part of Boreal Realm so far as known. California Coast Ranges (see Pessagno, 1977a and loc. SA-43B), Baja California Sur, Greece.

Perispyridium tamanense Pessagno and Blome
Plate 1, figure 8

Perispyridium tamanense Pessagno and Blome, 1982, p. 295, pl. 6, figs. 1, 7, 8–11, 13, 14; pl. 7, fig. 3.

Range.—Upper part of Zone 3; lower Tithonian.

Occurrence.—Upper part of lower more massively-bedded portion of Taman Formation, east-central Mexico.

Family **ULTRANAPORIDAE** Pessagno, 1977b

Type genus.—*Ultranapora* Pessagno, 1977b.

Range.—Lower Jurassic to Upper Cretaceous.

Occurrence.—World-wide in Tethyan and Boreal realms.

Genus **NAPORA** Pessagno, 1977a

Type species.—*Napora bukryi* Pessagno, 1977a.

Remarks.—*Napora* differs from *Ultranapora* by possessing a much smaller cephalis and by lacking a cephalocone. In addition, the thorax of *Napora s.s.* is inflated and nearly hemispherical whereas that of *Ultranapora* is typically pyramidal.

Range and occurrence.—Lower Jurassic to Cretaceous. Boreal and Tethyan realms.

Napora lospensis Pessagno
Plate 2, figure 9

Napora lospensis Pessagno, 1977a, p. 96, pl. 12, figs. 9, 10 [not Baumgartner, DeWever, and Kocher, 1980, p. 57, pl. 3, fig. 4].

Remarks.—The form figured by Baumgartner, DeWever, and Kocher as *Napora lospensis* Pessagno bears no resemblance to Pessagno's figured holotype. It possesses a longer, structurally different horn; longer, less massive feet; and much less massive pore frames.

Range.—Not fully established. Zone 2 to Zone 3; upper Kimmeridgian to lower Tithonian.

Occurrence.—California Coast Ranges so far as known.

Family **HSUIDAE** Pessagno and Whalen, 1982

Type genus.—*Hsuum* Pessagno, 1977a.

Range.—Zone 02 (Pessagno, Blome, Whalen, and Cheng, in prep.); Zone 1 to Zone 5, Subzone 5C; lower Pliensbachian to upper Valanginian part of Subzone 5C.

Occurrence.—World-wide in Tethyan and Boreal realms.

Genus **HSUUM** Pessagno, 1977a

Type species.—*Hsuum cuestaense* Pessagno, 1977a.

Range.—Same as for family.

Occurrence.—Most diversified and abundant in Boreal Realm. Rare in Tethyan realm at least in Late Jurassic.

Hsuum cuestaense Pessagno
(corrected name)
Plate 1, figure 5

Hsuum cuestaensis Pessagno, 1977a, p. 81, pl. 7, figs. 12, 13.

Remarks.—Although Pessagno (1977a) originally believed that this taxon ranged into Zone 5, he undoubtedly was confusing it with *H. mclaughlini* Pessagno and Blome, n. sp., and undescribed forms that likewise possess straight costae. There appears to be no evidence that this taxon ranges above Zone 3.

Range.—Zone 2 to upper part of Zone 3.

Occurrence.—California Coast Ranges, San Juan Islands (Trump Island), Pacific Rim complex of Vancouver Island.

Hsuum maxwelli Pessagno
Plate 1, figure 6

Hsuum maxwelli Pessagno, 1977a, p. 81, pl. 7, figs. 14–16.

Range.—Upper part of Zone 1; Zone 2 to middle part of Zone 3; upper Kimmeridgian to lower Tithonian (see Text-figs. 1, 3).

Occurrence.—California Coast Ranges (Pessagno, 1977a), Vancouver Island, Baja California Sur, Greece (Sample POB 899 from Baumgartner), Romania.

Hsuum mclaughlini Pessagno and Blome,
new species
Plate 1, figures 1–4, 12, 13, 17; Plate 5, figure 6

Etymology.—This species is named for Mr. Robert J. McLaughlin (U.S. Geological Survey, Menlo Park, Calif.) in honor of his significant contributions to the geology of the Geysers–Clear Lake Area, California Coast Ranges.

Description.—Test of medium width, rounded apically. Cephalis broad, hemispherical with short, massive horn. Thorax and subsequent chambers trapezoidal in outline, increasing rapidly in width (except for final post-abdominal chambers) and very slowly in length as added; final post-abdominal chambers narrower. Complete specimens with ten to twelve post-abdominal chambers. Inner latticed layer with small tetragonal (usually square) pore frames aligned in rows. Outer layer comprised of straight diverging costae and intercostal projections; intercostal projections well developed on proximal one-fourth to one-half of test tending to form a dense meshwork of massive irregular polygonal pore frames that completely obscure meshwork of the inner latticed layer. Costae straight usually, continuous distally, often tending to bifurcate in an apical direction. Eight to nine costae usually visible (side view) on final post-abdominal chambers.

Remarks.—*Hsuum mclaughlini* Pessagno and Blome, n. sp., differs from *H. cuestaense* Pessagno, 1977a, by having a wider test that is rounded rather than pointed apically and by usually developing a dense outer latticed layer proximally.

Measurements (in μm).—Ten specimens (holotype plus nine paratypes).

	length	width	number of post-abdominal chambers	horn length
Holotype (USNM 340257)	375	200	11	25
Mean	364.5	173.5	10	22.7
Maximum	420	200	12	25
Minimum	320	150	10	20

Type locality.—SA-43B. See Locality Descriptions.

Deposition of types.—Holotype: USNM 340257. Paratypes: USNM 340258 and Pessagno Collection.

Range.—Zone 4; upper Tithonian. See Text-figs. 1, 3.

Occurrence.—Volcanogenic-pelagic strata overlying Stanley Mountain remnant of Coast Range ophiolite at Alamo Creek. Locs. SA-39, SA-40, SA-42, SA-43B. Taman Formation of east-central Mexico at loc. MX-82-37; see Locality Descriptions. Southern part of Boreal Realm and northern part of Tethyan Realm.

Family **PARVICINGULIDAE** Pessagno, 1977a
(emend. Pessagno and Whalen, 1982)

Type genus.—*Parvicingula* Pessagno, 1977a.

Range.—Aalenian to lower Hauterivian.

Occurrence.—World-wide in Tethyan and Boreal realms.

Genus **MIRIFUSUS** Pessagno, 1977a

Type species.—*Mirifusus guadalupensis* Pessagno.

Range.—Base of Zone 2 to Zone 5, Subzone 5C; lower Kimmeridgian(?); upper Kimmeridgian to lower Hauterivian.

Occurrence.—World-wide in Tethyan and Boreal realms.

Mirifusus baileyi Pessagno
Plate 2, figures 1–3, 10, 13, 17, 21–23

Mirifusus baileyi Pessagno, 1977a, p. 83, pl. 10, figs. 6–8; pl. 11, figs. 9–11; Pessagno, 1977b, p. 48, pl. 8, fig. 1; not fig. 9; (?) fig. 8; Mizutani, 1981, p. 177, pl. 60, fig. 1.
Lithocampe mediodilatata Rüst, 1885. Moore, 1973, p. 828, pl. 2, ?figs. 5, 6; Riedel and Sanfilippo, 1974, p. 779, pl. 7, fig. 3; not figs. 1, 2, 4.
Mirifusus mediodilatata (Rüst). Baumgartner, DeWever, and Kocher, 1980, p. 56, pl. 5, fig. 11; not pl. 5, figs. 9, 10 (= *M. mediodilatata s.s.*).

Remarks.—Baumgartner, DeWever, and Kocher (1980) include *Mirifusus baileyi* Pessagno under *M. mediodilatata* (Rüst, 1885). As noted elsewhere in this report, these taxa not only display significantly different ranges, but also are morphologically distinct. *M. baileyi* possesses a very thick test wall. Most of its post-abdominal chambers are comprised of three layers of latticed meshwork. The inner layer consists of small, symmetrical pentagonal (not hexagonal as stated in Pessagno, 1977a) pore frames arranged in two staggered rows between closely-spaced, very nodose circumferential ridges. The two outer layers consist of two staggered rows of symmetrical triangular pore frames arranged between the circumferential ridges. On well-preserved specimens the bars of the triangular pore frames can be observed to connect with the nodes on the circumferential ridges. The circumferential ridges appear to be wedge-shaped in cross-section because they are considerably wider on the test exterior than they are in the test interior. The outer latticed layer of about the first eight post-abdominal chambers lacks staggered rows of triangular pore frames and consists rather of massive nodes interconnected by massive bars that tend to form triangular pore frames. It should be noted also that the two outer latticed layers of triangular pore frames are missing on the tubular extension of the final post-abdominal chamber and may be lacking on the last several post-abdominal chambers.

The test structure described above has been observed on numerous specimens from all over the world. In fact, it is well illustrated (except for the inner layer of triangular pore frames) by Baumgartner, DeWever, and Kocher (1980, pl. 5, fig. 11). The inner latticed layer of pentagonal pore frames can easily be observed by examining broken, well-preserved specimens.

M. mediodilatata (Rüst, 1885) *sensu* Pessagno (1977a) differs from *M. baileyi* by having a thinner test wall that appears to consist of an inner latticed layer of pentagonal pore frames arranged in two staggered rows between narrow, slightly nodose circumferential ridges. A partially formed outer (second) latticed layer consisting of nodes and interconnecting bars occurs on the apical portion of the test. As noted by Pessagno and Whalen (1982) in their analysis of parvicingulid wall structure, a microgranular layer commonly covers the latticed portion of *Mirifusus* apically.

Range.—Base of Zone 3 to top of Zone 5; upper Kimmeridgian(?); lower Tithonian to lower Hauterivian.

Occurrence.—World-wide. Tethyan and Boreal realms: California Coast Ranges, San Juan Islands, Alaska, Baja California Sur, east-central Mexico, Oman, Greece, Japan.

Mirifusus guadalupensis Pessagno
Plate 2, figures 12, 16, 24

Mirifusus guadalupensis Pessagno, 1977a, pp. 83, 84, pl. 10, figs. 9–14; Baumgartner, DeWever, and Kocher, 1980, p. 55, pl. 5, figs. 12–14.

Range.—Lower part of Zone 2 to lower part of Zone 3; upper Kimmeridgian; lower Tithonian(?).

Occurrence.—Southern part of Boreal realm; Tethyan Realm. See Pessagno (1977a) and Baumgartner, DeWever, and Kocher (1980).

Mirifusus mediodilatata (Rüst)
Plate 2, figures 4, 5, 18, 19

Lithocampe mediodilatata Rüst, 1885, p. 316, pl. 40 (15), fig. 9.
Mirifusus (?) *mediodilatata* (Rüst). Pessagno, 1977a, p. 84, pl. 11, figs. 1, 2.
Mirifusus mediodilatata (Rüst). Baumgartner, DeWever, and Kocher, 1980 (part), p. 56, pl. 5, figs. 9, 10; not pl. 5, fig. 11 (= *M. baileyi* Pessagno).

Range.—Zone 2 to Zone 5; upper Kimmeridgian to Valanginian.

Occurrence.—World-wide in Tethyan and Boreal realms.

Genus **PARVICINGULA** Pessagno, 1977a

Type species.—*Parvicingula santabarbaraensis* Pessagno, 1977a.

Range.—Base of Zone 1 to top of Zone 5: Middle Jurassic (Aalenian) to Lower Cretaceous (lower Hauterivian).

Occurrence.—Boreal Realm and northern part of Tethyan Realm. See discussion on pp. 18–19.

Parvicingula blowi Pessagno
Plate 2, figures 14, 15

Parvicingula blowi Pessagno, 1977a, p. 84, pl. 8, figs. 11–14.

Range.—Base of Zone 3 to middle part of Zone 4; upper Kimmeridgian(?); lower to upper Tithonian. See Text-figures 1, 3.

Occurrence.—California Coast Ranges (*cf.* Pessagno, 1977a), San Juan Islands (Trump Island).

Parvicingula colemani
Pessagno and Blome, new species
Plate 2, figures 6–8, 11, 20;
Plate 5, figures 2, 3

Etymology.—*P. colemani,* n. sp., is named for Dr. Robert G. Coleman (U.S. Geological Survey, Menlo Park, Calif.) in honor of his contributions to the study of ophiolites.

Description.—Test elongate, cylindrical to subcylindrical in aspect, blunt apically. Cephalis small, hemispherical with short, massive horn. Thorax trapezoidal with massive, variably sized and shaped polygonal pore frames. Abdomen trapezoidal to rectangular in outline, likewise with irregular polygonal pore frames; abdomen separated from first post-abdominal chamber by weakly-developed circumferential ridge. Eleven to 14 post-abdominal chambers, generally rectangular in outline, increasing slightly in width and height as added; separated by weakly-developed circumferential ridges. Pore frames of post-abdominal chambers of most specimens hexagonal in shape, arranged in three rows; central row of pore frames smaller in size, staggered with respect to those of two flanking rows. Some specimens with four rows of pore frames distally; pore frames of first and second post-abdominal chambers may be irregular. Final post-abdominal chamber terminating in broad tubular projection.

Remarks.—*Parvicingula colemani* Pessagno and Blome, n. sp., differs from *P. excelsa* Pessagno and Blome, n. sp., by having a cylindrical to subcylindrical test, a shorter, less massive horn, more weakly-developed circumferential ridges, and smaller pore frames on its post-abdominal chambers.

Measurements (in μm).—Ten specimens (holotype plus nine paratypes).

	length	width	number of post-abdominal chambers	horn length
Holotype (USNM 340259)	387.5	125	12	37.5
Mean	381	131.5	13	49.5
Maximum	437.5	150	14	60
Minimum	325	120	11	25

Type locality.—SA-43B. See Locality Descriptions.

Deposition of types.—Holotype: USNM 340259. Paratypes: USNM 340260 and Pessagno Collection.

Range.—Base of Zone 4 to upper part of Zone 4. Upper Jurassic: upper Tithonian. See Text-figures 1 and 3.

Occurrence.—In the California Coast Ranges *P. colemani* has been observed at Alamo Creek (Stanley Mountain remnant, Coast Range ophiolite) at locs. 81-CB-22, SA-40, SA-41, SA-42, and SA-43B; at Bitterwater Canyon (Llanada remnant, Coast Range ophiolite) at loc. SA-56; and in the Great Valley sequence at loc. NSF-837 (upper part of *B. piochii* Zone; upper Tithonian). Davila has encountered this species in a Zone 4 assemblage that is directly associated with *Buchia piochii* (Gabb, 1869) at his locality BJV-20 in Baja California Sur. *P. colemani* also occurs in the upper thin-bedded portion of the Taman Formation in east-central Mexico (locality MX-82-37) (see Locality Descriptions).

Parvicingula excelsa
Pessagno and Blome, new species
Plate 3, figures 1–4, 11–13, 17, 22;
Plate 5, figures 4, 5

Etymology.—*excelsus-a-um* (Latin, adj.) = lofty, high.

Description.—Test elongate, conical with small hemispherical cephalis possessing a massive, moderately long, conical, pointed horn; thorax and subsequent chambers trapezoidal in outline. Cephalis and much of thorax covered by layer of microgranular silica. Apical portion of test (cephalis through abdomen) inflated, turret-like. Abdomen with variably-sized polygonal pore frames not arranged in rows. Abdomen separated from first post-abdominal chamber, and subsequent post-abdominal chambers separated from each other, by well-developed circumferential ridges. Post-abdominal chambers with three rows of hexagonal pore frames; center row of pore frames somewhat smaller than flanking rows; with elliptical rather than circular pores, staggered with respect to pore frames of flanking rows. Most complete tests with ten to fifteen post-abdominal chambers that change rapidly in width and more slowly in height as added. Terminal tube not observed on type specimens.

Remarks.—*Parvicingula excelsa* Pessagno and Blome, n. sp., differs from *P. elegans* Pessagno and Whalen, 1982, by possessing a longer, somewhat more slender test with a much larger and more massive horn and by having its cephalis and thorax covered with microgranular silica. Both species have tests that are swollen and turret-like apically and have three rows of hexagonal pore frames on their post-abdominal chambers. The pore frames of *P. excelsa* n. sp., though similar in shape to those of *P. elegans,* tend to be considerably more massive.

Measurements (in μm).—Eleven specimens (holotype plus ten paratypes).

	length	width	number of post-abdominal chambers	horn length
Holotype (USNM 340261)	375	150	11	50
Mean	374.4	139.5	12	60.6
Maximum	437.5	160	15	75
Minimum	300	125	10	45

Type locality.—SA-43B. See Locality Descriptions.

Deposition of types.—Holotype: USNM 340261. Paratypes: USNM 340262 and Pessagno Collection.

Range.—Zone 4; upper Tithonian. See Text-figures 1 and 3.

Occurrence.—Volcanogenic-pelagic sediments occurring above Coast Range ophiolite at Stanley Mountain (Alamo Creek locs. SA-39, SA-40, SA-41, SA-42, SA-43B) and at Llanada (Bitterwater Canyon loc. SA-58). Near base of Great Valley sequence at loc. MG-77-3 (see Locality Descriptions).

Parvicingula jonesi Pessagno
Plate 3, figures 5–7, 14, 19, 24, 25

Parvicingula jonesi Pessagno, 1977b, p. 48, pl. 8, fig. 14.

Remarks.—Pessagno (1977b) supplied only one illustration of the holotype of this species. Other illustrations are offered herein to demonstrate variations in test breadth, length, and number of post-abdominal chambers. The specimen (Pl. 4, figs. 6, 14, 19, 24) from loc. MG-77-3 differs from the holotype by possessing more post-abdominal chambers and by being somewhat more slender. Nevertheless, it displays the three rows of equal-sized pentagonal pore frames between circumferential ridges, the dome-like cephalis, and the short horn that typify this species. Specimens similar to this form (Pl. 4, fig. 7), but not as well preserved, are common in the type material.

Range.—Zone 4 to Zone 5, Subzone 5A; upper Tithonian to Berriasian. In California and Baja California Sur this species has been only observed in strata assigned to the *Buchia piochii* Zone and the *Buchia uncitoides* Zone (Jones, Bailey, and Imlay, 1969). However, in east-central Mexico *P. jonesi* occurs in the upper thin-bedded part of the Taman Formation (loc. MX-82-37; upper Tithonian).

Occurrence.—California Coast Ranges (locs. NSF-805, NSF-818, NSF-821, NSF-823, NSF-825, NSF-837, NSF-838, and NSF-945; loc. MG-77-3; upper Tithonian). Lower Cretaceous occurrences shown in Pessagno (1977b). Baja California Sur, Mexico in the Eugenia Formation (loc. BJV-20). Upper thin-bedded part of the Taman Formation of east-central Mexico at locality MX-82-37 (see Locality Descriptions).

Parvicingula santabarbaraensis Pessagno
Plate 3, figure 8

Parvicingula santabarbaraensis Pessagno, 1977a, p. 86, pl. 9, figs. 11–13.

Range.—Upper part of Zone 2 to lower part of Zone 4; upper Kimmeridgian to upper Tithonian.

Occurrence.—California Coast Ranges (*see* Pessagno, 1977a). Locs. SA-35, SA-42, SA-43B at Alamo Creek (Stanley Mountain remnant of Coast Range ophiolite) (see Locality Descriptions). Boreal Realm so far as known.

Parvicingula vera Pessagno and Whalen
Plate 3, figures 15, 20, 21

Parvicingula vera Pessagno and Whalen, 1982, p. 144, pl. 11, figs. 3–5, 11, 19; pl. 13, fig. 8.

Range.—Middle Jurassic (upper Bathonian) to Upper Jurassic (upper Kimmeridgian). Zone 1 to Zone 2.

Occurrence.—Snowshoe Formation of east-central Oregon. Taman Formation of east-central Mexico. Northern part of Tethyan Realm to central part of Boreal Realm.

Genus **RISTOLA** Pessagno and Whalen, 1982

Type species.—*Ristola procera* Pessagno (1977a).

Range.—Middle Jurassic to Lower Cretaceous.

Occurrence.—World-wide in Tethyan and Boreal realms.

Ristola altissima (Rüst)
Plate 3, figure 10

Lithocampe altissima Rüst, 1885, p. 315(45), pl. 40(15), fig. 2.
Parvicingula(?) *altissima* (Rüst). Pessagno, 1977a, p. 85, pl. 8, figs. 9, 10; Baumgartner, DeWever, and Kocher, 1980, p. 58, pl. 5, figs. 4–7.

Range.—Lower part of Zone 3 to top of Zone 4; upper Kimmeridgian(?); lower Tithonian to uppermost Tithonian.

Occurrence.—World-wide in Tethyan and Boreal realms. California, Baja California Sur, San Juan Islands, Alaska, Oman, Greece, Romania, Italy, DSDP Site 367 (Cape Verde Basin), Puerto Rico [see data presented by Baumgartner, DeWever, and Kocher (1980) and Tippit (1981)].

Ristola boesii (Parona) *sensu lato*
Plate 3, figure 9

Dictyomitra boesii Parona, 1890, p. 170, pl. 6, fig. 9.

Remarks.—To date, no form figured in the literature as *R. boesii* (Parona) corresponds to Parona's figured

type. Parona's figured type possesses a short, moderately spindle-shaped test with a rounded apical portion. Thin circumferential ridges separate six post-abdominal chambers. Three rows of equal-sized pores occur between the circumferential ridges. It is impossible to determine the shape of the pore frames from the illustration.

The form figured herein shows some of the features illustrated by Parona. It displays three rows of equal-sized pore frames between circumferential ridges; the ridges are of moderate relief; and the apical portion of the test is rounded. It differs, however, in that the test is slightly less inflated medially and is hence, less spindle-shaped. The apical portion of the test, though rounded, is slightly narrower and the test possesses seven rather than six post-abdominal chambers. Since this form differs somewhat from Parona's type specimen, it is referred to herein as *R. boesii s.l.*

R. boesii (Parona) is rapidly becoming a "wastebasket" name utilized by workers to include all remotely similar Nassellaria. It is conceivable that Parona's illustration of his type specimen is too schematic to allow accurate correlation with any known morphotype. To stabilize the already chaotic nomenclature surrounding this taxon, it may be necessary to re-illustrate Parona's type specimen if it can be located or to erect a neotype.

Range and occurrence.—California Coast Ranges at loc. NSF-1068 (*B. pacifica* Zone; lower to middle Valanginian) [see Pessagno (1977b)].

Ristola sp. aff. **R. boesii** (Parona, 1890)
Plate 3, figures 16, 18, 23

Remarks.—This form differs from Parona's type by being less inflated, having different pore structure between its circumferential ridges, and by having seven rather than six post-abdominal chambers. It may actually be more closely related to *R. hsui* Pessagno, 1977a, than to *R. boesii.*

Range and occurrence.—Zone 5, Subzone 5B. California Coast Ranges at loc. NSF-845 (*B. pacifica* Zone: lower to middle Valanginian; see Pessagno, 1977b).

Ristola sp. cf. **R. boesii** (Parona, 1890)
Plate 4, figures 7, 17

Range and Occurrence.—Zone 4 in California and Baja California Sur. A similar, if not identical form, occurs in Tithonian(?), Berriasian to lower Hauterivian strata in Oman (Tippit, 1981).

Ristola hsui (Pessagno)
Plate 4, figures 2, 3

Parvicingula hsui Pessagno, 1977a, p. 85, pl. 8, figs. 15, 16; pl. 9, figs. 1–5.

Remarks.—Although Pessagno (1977a) originally believed that this taxon possessed a short, massive horn and hence, should be included in *Parvicingula* Pessagno, this interpretation is now regarded as invalid. The short horn noted by Pessagno simply represents the pointed apical portion of the cephalis.

Range.—Zone 3 to lower part of Zone 4; upper Kimmeridgian(?); lower Tithonian to upper Tithonian.

Occurrence.—Boreal Realm. California Coast Ranges. In addition to occurrences noted by Pessagno (1977a), *R. hsui* also occurs in the Alamo Creek succession (Stanley Mountain remnant of Coast Range ophiolite) at the following localities: SA-33 through 35; SA-37 through 43B. San Juan Islands (Trump Island). Baja California Sur.

Ristola procera (Pessagno)
Plate 4, figure 6

Parvicingula(?) *procera* Pessagno, 1977a, p. 86, pl. 9, figs. 6–9.
Parvicingula procera Pessagno. Baumgartner, DeWever, and Kocher, 1980, p. 60, pl. 5, fig. 8.

Range.—Zone 2 to top of Zone 4; Kimmeridgian to upper Tithonian.

Occurrence.—California Coast Ranges (Pessagno, 1977a). Southern Europe (Baumgartner, DeWever, and Kocher, 1980).

Family **SPONGOCAPSULIDAE** Pessagno, 1977a

Type genus.—*Spongocapsula* Pessagno, 1977a.

Range and occurrence.—Middle Jurassic to Upper Cretaceous. World-wide in Boreal and Tethyan realms.

Genus **OBESACAPSULA** Pessagno, 1977a

Type species.—*Obesacapsula morroensis* Pessagno, 1977a.

Range and occurrence.—Upper Jurassic to Lower Cretaceous; world-wide in Boreal and Tethyan realms.

Obesacapsula morroensis Pessagno
Plate 4, figure 5

Obesacapsula morroensis Pessagno, 1977a, p. 87, pl. 11, figs. 5–8.

Range.—Zone 2 to Zone 5, Subzone 5C; upper Kimmeridgian (Text-figs. 1, 3) to upper Valanginian.

Occurrence.—California Coast Ranges (Pessagno, 1977a). Baja California Sur.

Obesacapsula rotunda (Hinde)
Plate 4, figures 8, 10

Stichocapsa rotunda Hinde, 1902, p. 41, pl. 3, fig. 24.
Stichocapsa(?) *rotunda* Hinde. Foreman, 1973, p. 265, pl. 11, figs. 1, 2; pl. 16, fig. 20.
Obesacapsula rotunda (Hinde). Pessagno, 1977b (part), p. 53, pl. 9, figs. 12, 18; not pl. 9, fig. 4.

Remarks.—The morphotype figured herein and by Pessagno (1977b, pl. 9, figs. 12, 18; not fig. 4) corresponds closely to those figured by Foreman (1973, 1978) and Baumgartner, DeWever, and Kocher (1980). However, we have never observed this form below the base of the Lower Cretaceous (Berriasian). Baumgartner, DeWever, and Kocher (1980) extended the range of *O. rotunda* into their Upper Jurassic Biochronozone C. We suspect that these workers may have included the form referred to herein as *O.* sp. aff. *O. rotunda* (Hinde) under *O. rotunda.* This was also done in part by Pessagno (1977b, pl. 9, fig. 4).

Range.—Zone 5. Berriasian to lower Hauterivian.

Occurrence.—Numerous localities in Boreal and Tethyan realms. World-wide.

Obesacapsula sp. aff. **O. rotunda** (Hinde)
Plate 4, figure 9

Obesacapsula rotunda (Hinde, 1902). Pessagno, 1977b (part), p. 53, pl. 9, fig. 4; not pl. 9, figs. 12, 18.

Remarks.—This form differs from *O. rotunda* (Hinde, 1902) *s.s.* by having less inflated post-abdominal chambers separated by less pronounced strictures. The apical portion of the test of *O.* sp. aff. *O. rotunda* tends to be much more elongate. It is likely that *O.* sp. aff. *O. rotunda* gave rise to *O. rotunda.*

Range.—Zone 3 to Zone 5, Subzone 5B so far as known; upper Kimmeridgian (?); lower Tithonian to middle Valanginian.

Occurrence.—California Coast Ranges (locs. NSF-845, NSF-908; SA-43B; see Locality Descriptions). Baja California Sur (Davila, in prep.).

NASSELLARIINA *incertae sedis*

GENERA AND INCLUDED SPECIES NOT ASSIGNED TO A FAMILY

Genus **ANDROMEDA** Baumgartner *in* Baumgartner, DeWever, and Kocher, 1980

Type species.—*Andromeda crassa* Baumgartner, 1980b.

Range and occurrence.—Lower to Upper Jurassic in Boreal and Tethyan realms.

Andromeda violae Baumgartner
Plate 4, figures 16, 18, 19

Andromeda violae Baumgartner, 1980b, in Baumgartner, DeWever, and Kocher, 1980, p. 50, pl. 4, figs. 10–14; pl. 6, fig. 11.

Range.—Zone 2 to lower part of Zone 4 so far as known; Kimmeridgian to upper Tithonian.

Occurrence.—Italy, Sicily, Greece, Cape Verde Basin (See Baumgartner, DeWever, and Kocher, 1980). California Coast Ranges at Point Sal (loc. NSF-907) and at Alamo Creek (Stanley Mt.; locs. NSF-973; SA-43B) (see Locality Descriptions).

Genus **SAITOUM** Pessagno, 1977a

Type species.—*Saitoum pagei* Pessagno, 1977a.

Range and occurrence.—Mesozoic. World-wide.

Saitoum pagei Pessagno
Plate 4, figures 4, 11

Saitoum pagei Pessagno, 1977a, p. 98, pl. 12, figs. 11–14.

Range.—Zone 1(?); Zone 2 to Zone 3. Kimmeridgian to lower Tithonian.

Occurrence.—California Coast Ranges. See Pessagno (1977a).

Genus **TURANTA** Pessagno and Blome, 1982

Type species.—*Turanta capsensis* Pessagno and Blome, 1982.

Range.—Base of Zone 1 to lower part of Zone 3; uppermost Toarcian/lowermost Bajocian to lower Tithonian.

Occurrence.—California Coast Ranges, Baja California Sur, and east-central Oregon. See Pessagno and Blome (1982).

Turanta flexa Pessagno and Blome
Plate 4, figure 15

Turanta flexa Pessagno and Blome, 1982, p. 298, pl. 6, figs. 5, 6.

Range.—Zone 2 to lower part of Zone 3 so far as known.

Occurrence.—California Coast Ranges, Baja California Sur.

SPECIES THAT NEED TO BE REASSIGNED TO NEW GENERA

"Eucyrtidium" ptyctum Riedel and Sanfilippo
Plate 4, figures 12–14

Eucyrtidium ptyctum Riedel and Sanfilippo, 1974, p. 778, pl. 5, fig. 7; pl. 12, fig. 13. Baumgartner, DeWever, and Kocher, 1980, p. 53, pl. 3, fig. 13.
Eucyrtidium(?) *ptyctum* Riedel and Sanfilippo. Pessagno, 1977a, p. 94, pl. 12, fig. 7.

Remarks.—This taxon is virtually unrelated morphologically to *Eucyrtidium* Ehrenberg, 1847, and should be assigned to a new genus. The type species of *Eucyrtidium, Lithocampe acuminata* Ehrenberg, 1844, is a multicyrtid form lacking strictures. "*E.*" *ptyctum,* however, is a tricyrtid form possessing a weakly developed stricture between the cephalis and thorax and a prominent stricture between the thorax and abdomen. A cephalopyle (Pl. 4, figs. 13, 14) is present at the base of the cephalis. Rows of small pores

occur in the stricture between the thorax and abdomen and at the base of the abdomen (Pl. 4, figs. 12, 13).

Range.—Upper Zone 1; Zone 2 to upper Zone 4; Kimmeridgian to upper Tithonian. This species has only been observed to date as high as the lower part of Zone 4 in the California Coast Ranges (See Pessagno, 1977a; locs. SA-4, SA-5, SA-16, SA-29, SA-30, SA-39, SA-42, SA-43 at Alamo Creek). However, Davila (in prep.) has found it associated with common to abundant *Buchia piochii* in Baja California Sur.

Occurrence.—Boreal and Tethyan realms, worldwide [see Pessagno (1977a) and Baumgartner, DeWever, and Kocher (1980)].

"Hsuum" stanleyense Pessagno
(corrected name)
Plate 4, figure 1

Hsuum(?) *stanleyensis* Pessagno, 1977a, p. 82, pl. 8, figs. 5–8.

Remarks.—This species lacks the layered wall structure described by Pessagno and Whalen (1982) for *Hsuum* Pessagno, 1977a, and other members of the Hsuidae Pessagno and Whalen, 1982. At the moment it cannot be assigned in good conscience to any known Mesozoic genus.

Range.—Upper part of Zone 1(?) to Zone 2; lower to upper Kimmeridgian.

Occurrence.—California Coast Ranges. See Pessagno (1977a). Boreal Realm.

APPENDIX

LOCALITY DESCRIPTIONS

Introduction.—In the California Coast Ranges samples are prefixed by NSF, SA, MG, 74-JP, and BK by the various collectors. NSF samples and SA samples were collected by the senior author and by the senior author and Mr. Stephen Atlas respectively. Samples prefixed by MG and 74-JP were collected by Mr. Robert McLaughlin and Dr. David L. Jones (U.S. Geological Survey, Menlo Park, CA). The sample prefixed by BK was collected by James Berkland.

The single sample prefixed by OR was collected by Pessagno and Blome from east-central Oregon.

All samples from east-central Mexico are prefixed by MX and were collected by Pessagno and Longoria during the 1980, 1981, and 1982 field seasons. The prefix BJV is used for samples collected by Pessagno, Longoria, and Davila from the Vizcaino Peninsula, Baja California Sur, Mexico.

California

Volcanogenic-pelagic Strata Associated with the Coast Range Ophiolite

1. Point Sal, Santa Barbara Co.: 21 m (70 ft) of green to gray tuffaceous chert and lenticular masses or nodules of pelagic limestone overlying Coast Range ophiolite (see Pessagno, 1977a; Hopson, Mattinson, and Pessagno, 1981; Text-fig. 2). USGS Point Sal Quadrangle (7.5′): T. 10 N., R. 36 W.; near western edge of sect. 34. 0.9 km (0.6 mi) N 15° W of west side of Lion Rock.

NSF-900. Greenish-gray, thin-bedded tuffaceous chert. Composite sample from lower 0.9 m (3 ft) of chert. Zone 1?

NSF-904. Greenish-gray to gray, thin-bedded tuffaceous chert. 4.5 m (15 ft) above contact with ophiolite. Base of Zone 2. *Note:* In that the tuffaceous chert becomes progressively more recrystallized below NSF-904 in the section, the absence of *Mirifusus* in the assemblage may be diagenetically controlled.

NSF-907. Lens of gray tuffaceous limestone about 0.4 m (1.5 ft) thick. 11.5 m (38 ft) above the contact with the ophiolite. Zone 2 (upper part).

NSF-908. Small limestone nodules occurring at 13.4 m (44 ft) above the contact with the ophiolite. Zone 3 (near base).

NSF-909. Small limestone nodule in green tuffaceous chert; 15.8 m (52 ft) above contact with the ophiolite. Zone 3.

2. Alamo Creek (Stanley Mountain remnant of Coast Range ophiolite), San Luis Obispo Co.: 103 m (338 ft) of tuffaceous chert, tuff breccia, and pelagic limestone overlying Coast Range ophiolite (see Hopson, Mattinson, and Pessagno, 1981; Text-fig. 2). USGS Huasna Peak Quadrangle (7.5′): T. 12 N., R. 32 W.; northwestern part of sect. 32; southwestern part of sect. 29.

SA-4. Thin-bedded, reddish brown, tuffaceous chert. 3.8 m (9.4 ft) above the contact with the ophiolite. These strata are questionably assigned to Zone 1. Chert strata below this horizon are recrystallized and contain only poorly preserved Radiolaria.

SA-5. Same. 4.7 m (15.5 ft) above contact with ophiolite. Apparent base of Zone 2 (with *Mirifusus* Pessagno, 1977a).

SA-11. Same. 17.0 m (56 ft) above contact with the ophiolite. Lower part of Zone 2.

SA-16. Same. 20.7 m (68 ft) above contact with the ophiolite. Zone 2.

NSF-972. Medium gray pelagic limestone (tuffaceous micrite) bed 30 cm (8 in) thick. 21 m (69.5 ft) above contact with the ophiolite. Zone 2.

NSF-973. Dark gray limestone (micrite) bed 15 to 20 cm (6 to 8 in) thick. 45.5 m (149.5 ft) above contact with the ophiolite. Zone 2.

SA-29. Thin-bedded, dark gray, tuffaceous chert. 58.5 m (192 ft) above the contact with the ophiolite. Zone 2.

SA-30. Same. 60.6 m (199 ft) above contact with ophiolite. Apparent top of Zone 2. Note: The absence of *Parvicingula* Pessagno, 1977a, *s.s.* (possessing narrow, elongate tube on final postabdominal chamber) may suggest that the interval from locs. SA-30 to SA-4 is assignable to the lower half of Zone 2. *Parvicingula s.s.* makes its first appearance in the upper half of Zone 2 in the Taman Formation of east-central Mexico. This

suggests that an unconformity and hiatus exist in the interval between locs. SA-30 and SA-31.

SA-31. Thin-bedded, reddish brown, tuffaceous chert. 62 m (204.5 ft) above contact with ophiolite. Zone 3. The interval of concurrence between *Mirifusus guadalupensis* Pessagno, 1977a, and *M. baileyi* Pessagno, 1977a, has not been recognized in this section. Either this interval is condensed or is absent due to the unconformity and hiatus suggested above.

SA-33. Same. 75 m (247 ft) above contact with the ophiolite. Zone 3.

SA-35. Dark gray tuffaceous, micritic limestone bed 20.3 cm (8 in) thick. 79.5 m (261 ft) above contact with ophiolite. Zone 3.

SA-37. Thin-bedded, reddish brown tuffaceous chert. 82 m (269 ft) above contact with the ophiolite. Zone 3.

SA-38. Same. 84 m (277 ft) above the contact with the ophiolite. Zone 3, near top.

SA-39. (= 81-CB-22) Same. 90 m (296 ft) above contact with ophiolite. Zone 4, at, or somewhat above, base (sample 81-CB-22 collected by C. D. Blome).

SA-40. Same. 92.6 m (304 ft) above contact with ophiolite. Zone 4.

SA-41. Same. 97 m (318 ft) above contact with ophiolite. Zone 4.

SA-42. Same. 98 m (322 ft) above contact with ophiolite. Zone 4.

SA-43B. Silty, dark gray limestone bed 5 cm (2 in) thick. 100.6 m (330 ft) above contact with ophiolite: 2.4 m (8 ft) below top of exposed section. Covered interval separates tuffaceous chert from faulted contact with Great Valley sequence (See Hopson, Mattinson, and Pessagno, 1981). Zone 4.

3. Llanada (Bitterwater Canyon), San Benito Co.: 1245 m (4083 ft) of tuff breccia and tuffaceous chert overlying Coast Range ophiolite (see Hopson, Mattinson, and Pessagno, 1981; Text-fig. 2). Tuff-breccia predominates in this section.

SA-56. Greenish-gray, tuffaceous chert near contact with Great Valley Sequence. USGS Llanada Quadrangle (7.5′): T. 15 S., R. 9 E.; at point of juncture of sects. 26, 27, 34, and 35. Zone 4.

SA-58. Lens of greenish-gray, tuffaceous chert in tuff breccia. 4.5 m (15 ft) below contact with Great Valley Sequence. Overlying Great Valley Sequence in this area assignable to the *Buchia piochii* Zone of Jones, Bailey, and Imlay (1969) (see Text-figs. 2 and 3). USGS Llanada Quadrangle (7.5′): T. 15 S., R. 9 E.; southeast ¼ sect. 26. 0.8 km (0.5 mi) southeast of Albanez Spring (sect. 27), along southeast trending tributary of Bitterwater Canyon. Zone 4.

4. Dismembered ophiolite at Wilbur Springs, Colusa County.

NSF-997. Red manganiferous chert interbedded with vesicular basalt. Ridge west of east fork of Sulphur Creek. 0.56 km (0.35 mi) S 69° W of Eagle Rock. USGS Wilbur Springs Quadrangle (7.5′): T. 14 N., R. 5 W.; sect. 18. Zone 3.

Great Valley Sequence

1. Grindstone Creek, Glenn Co.: 365 m (1200 ft) of interbedded sandstones and shales exposed along Grindstone Creek. Section includes (ascending order) the *Buchia piochii* Zone (upper Tithonian), the *B.* sp. aff. *B. okensis* Zone (upper Tithonian), the *B. uncitoides* Zone (Berriasian), the *B. pacifica* Zone (lower to middle Valanginian), the *B. keyserlingi* Zone (pt.) (middle to upper Valanginian) [see Jones, Bailey, and Imlay (1969); Pessagno (1977b)]. USGS Chrone Quadrangle (7.5′): T. 21 N., R. 6 W. Megafossils identified in samples below by Dr. D. L. Jones (USGS, Menlo Park, CA).

NSF-803. Large dark gray limestone (micrite) nodule with calcified Radiolaria, *Buchia* sp. aff. *B. okensis* (Pavlow, 1907), and *Lytoceras* sp. 248 m (815 ft) west of gaging station and eastern border of sect. 16 along south side of Grindstone Creek. Zone 4.

NSF-804. Small dark gray limestone (micrite) nodule with Radiolaria. 234 m (767.4 ft) west of gaging station and eastern border of sect. 16 along south side of Grindstone Creek. Zone 4.

NSF-805. Small, dark gray limestone nodule (micrite) with pyritized Radiolaria. 219 m (718 ft) west of gaging station and eastern border of sect. 16 along south side of Grindstone Creek. Zone 4.

NSF-808. Large, dark gray limestone (micrite) nodule with *Buchia uncitoides* (Pavlow, 1907). 183 m (603 ft) west of gaging station and eastern border of sect. 16 along south side of Grindstone Creek.

NSF-810. Dark gray limestone nodules with *Buchia uncitoides* (Pavlow, 1907), and calcified Radiolaria. 16.3 m (537 ft) west of gaging station and eastern border of sect. 16 along south side of Grindstone Creek [see Pessagno (1977b)]. Zone 5, Subzone 5A.

2. Middle Fork of Elder Creek, Tehama Co. [see Jones, Bailey, and Imlay (1969) and Pessagno (1977a)].

NSF-821. Dark gray limestone (micrite) nodule near middle of *Buchia piochii* Zone. USGS Lowrey Quadrangle (7.5′): T. 25 N., R. 6 W.; northwest part of sect. 30 on side of hill immediately east of Rouse Gardens; 2.6 km (1.5 mi) due west of Lowrey Road. Zone 4.

NSF-823. Dark gray limestone (micrite) nodule. Upper part of *Buchia piochii* Zone of Jones, Bailey, and Imlay (1969). 1.4 km (0.9 mi) S 69° W of northwest corner of Lowrey Cemetery. USGS Lowrey Quadrangle (7.5′): T. 25 N., R. 6 W.; north-central part of sect. 30. Zone 4.

3. McCarty Creek area, Tehama Co. [see Pessagno (1977a, 1977b) and Jones, Bailey, and Imlay (1969)].

NSF-837. Dark gray limestone (micrite) nodule near McCarty Creek. Upper part of *Buchia piochii* Zone. Road between Paskenta and Patton along Digger Creek. Slightly less than 0.48 km (0.3 mi) east of BM 1009 along road. USGS Paskenta Quadrangle (7.5′): T. 24 N., R. 7 W.; sect. 25. Zone 4.

NSF-838. Dark gray limestone (micrite) nodule. Uppermost part of *Buchia* sp. aff. *B. okensis* Zone along McCarty Creek (see Pessagno, 1977b, p. 8, fig. 2). USGS Paskenta Quadrangle (7.5′): T. 24 N., R. 6 W.; middle of boundary between sects. 19 and 30. Zone 4.

NSF-845. Medium gray limestone (micrite) nodule occurring in dark gray mudstone. Upper part of *Buchia pacifica* Zone (see Pessagno, 1977b, p. 8, fig. 2). USGS Paskenta Quadrangle (7.5′): T. 24 N., R. 6 W.; NE ¼ of sect. 29. Zone 5, Subzone 5B.

NSF-1019. Dark gray limestone (micrite) nodule. Upper part of *Buchia keyserlingi* Zone (upper Valanginian; see Jones, Bailey, and Imlay, 1969; Pessagno, 1977b, p. 8, fig. 2). USGS Paskenta Quadrangle (7.5′): T. 24 N., R. 6 W.; at boundary between NE ½ and NW ½ of sect. 28 along McCarty Creek.

NSF-1068. Dark gray limestone (micrite) nodule. Lower part of *Buchia pacifica* Zone (lower to middle Valanginian; see Jones, Bailey, and Imlay, 1969; Pessagno, 1977b) exposed along McCarty Creek. USGS Paskenta Quadrangle (7.5′): T. 24 N., R. 6 W.; NW ¼ of sect. 29. Zone 5, Subzone 5C.

Miscellaneous Localities in the Franciscan Complex and the Great Valley Sequence

BK-605. Red radiolarian chert in Franciscan melange. USGS Potter Valley Quadrangle (7.5′): T. 16 N., R. 11 W.; NE ¼ of sect. 8. Potter Valley Road; 0.3 km (0.18 mi) southwest of junction of Guntley Ranch Road with Potter Valley Road and California Route 20. Sample from James Berkland (Univ. California, Davis).

MG-77-3. (= loc. 10 of McLaughlin and Pessagno, 1978, p. 721, fig. 2). Limestone nodule in mudstone of Great Valley sequence. Approximately 76 m (249 ft) above sedimentary contact with Coast Range ophiolite at Mount St. Helena. USGS Mount St. Helena Quadrangle (7.5′): T. 10 N., R. 7 W.; 701.5 m N, 793 m W, SE corner of sect. 20. Sample collected by Mr. R. J. McLaughlin (USGS, Menlo Park). Zone 4.

74-JP-1. Great Valley sequence. Medium gray, laminated mudstone with *Buchia rugosa* (Fischer, 1830–1837) and specimens transitional between *Buchia rugosa* and *Buchia concentrica* (Sowerby, 1827). Sample collected by Dr. D. L. Jones (USGS, Menlo Park, Calif.) near Crowfoot Point. Zone 2.

Oregon

East-central Oregon. John Day Inlier (see Pessagno and Whalen, 1982).

OR-501C. South Fork Member of Snowshoe Formation of east-central Oregon (see Smith, 1980). Dark gray mudstone with common micritic limestone nodules. USGS Izee Quadrangle (7.5′): T. 17 N., R. 23 E.; SE ¼ of sect. 29 (eastern edge). Outcrop on north side of State Highway 63; about 0.64 km (0.4 mi) east of Izee.

Mexico

East-Central Mexico

Taman Formation (Heim, 1926). Taman–Tamazunchale area, San Luis Potosi.

MX-80-20. Middle portion of lower, more massively-bedded part of Taman Formation. Medium bedded, dark gray, micritic limestone with ammonites and abundant *Aulacomyella* Furlani, 1910. An ammonite submitted to Dr. R. W. Imlay (U.S. Geol. Survey, Washington, DC) for identification was said to greatly resemble *Subneumayria profulgens* (Burckhardt, 1906). *Subneumayria* Spath, 1924, is characteristic of the "*Idoceras* beds" of Mexico (see Arkell, Kummel, and Wright, 1957, p. 327) and hence, would be characteristic of the *Idoceras* Zone of Cantu Chapa (1971) (upper lower Kimmeridgian). 0.2 km west of km post 264 on Rt. 85 (Mexico, D.F.—Nuevo Laredo Highway); 3.8 km east-northeast of the village of Taman, S. L. P.

MX-80-23. Upper portion of lower, more massively-bedded part of Taman Formation. Dark gray, medium to massively-bedded micritic limestone with abundant *Aulacomyella* Furlani, 1910. Interbedded black shales with limestone nodules. *Idoceras* Zone or *Glochiceras* gr. *fialar* Zone of Cantu Chapa (1971); probably *G.* gr. *fialar* Zone. Uppermost lower Kimmeridgian to upper Kimmeridgian; probably upper Kimmeridgian. About 6 km south of Tamazunchale along Rt. 85 (Mexico, D. F.—Nuevo Laredo Highway) near km post 267 (= old 350). Zone 2.

MX-81-54. Upper portion of lower, more massively-bedded part of Taman Formation. Medium- to massively-bedded, dark gray, micritic limestone with thin shale intervals containing limestone nodules. Lower Tithonian part of Zone 3. Near final occurrence of *Aulacomyella* Furlani, 1910, and top of *Virgatosphictes mexicanus–Aulacomyella neogeae* Zone of Cantu Chapa (1971). 25 m below first occurrence of calpionellids in lower part of upper thin-bedded Taman. 0.75 km west-southwest of hanging bridge over Río Moctezuma at La Vega Larga along Rt. 85 (Mexico, D.F.—Nuevo Laredo Highway); about 5.75 km west-southwest of Tamazunchale, S. L. P.

MX-82-3. Lower portion of lower, more massively-bedded part of the Taman Formation. Platy, thin-bedded, dark gray, micritic limestone interbedded with medium bedded dark gray, micritic limestone. Above first occurrence of *Aulacomyella* Furlani, 1910, in the Taman Formation. 0.3 km east-northeast of MX-80-20 (see above). Somewhat east-northeast of km post 264 on Rt. 85 (Mexico, D.F.—Nuevo Laredo Highway); 4.2 km east-northeast of village of Taman, S. L. P. Zone 1.

MX-82-8. Lower portion of lower, more massively-bedded part of Taman Formation. Predominantly medium bedded, dark gray, micritic limestone with occasional thin beds 10.2 cm (4 in) to 20.3 cm (8 in) thick. Samples from adjacent 10.2 cm (4 in) and 20.3 cm (8 in) layers. First occurrence of *Mirifusus* Pessagno, 1977a. Apparent base of Zone 2. Adjacent to and slightly east of km post 266 on Rt. 85 (Mexico, D.F.—Nuevo Laredo Highway); 6 km east-northeast of village of Taman, S. L. P.

MX-82-37. Lower portion of thin-bedded upper part of Taman Formation (= lower Pimienta of Cantu Chapa, 1971). Thin-bedded, black micritic limestone with thick beds of black, yellowish weathering shale containing abundant, black, micritic, fist-sized limestone nodules. Thin-bedded upper Taman occurring in tight, overturned, synclinal fold; infolded into lower massively-bedded part of Taman. (Note: Same synclinal structure with infolded upper Taman exposed on Rio Moctezuma below, slightly west of hanging bridge.) Zone 4 (lower part). Above last occurrence of *Aulacomyella* Furlani, 1910, in more massively-bedded part of Taman and hence, above the *Virgatosphinctes mexicanus–Aulacomyella neogeae* Zone of Cantu Chapa (lower Tithonian); equivalent to *Mazapilites* Zone of Cantu Chapa (1971). The occurrence of calpionellids in the lower part of the thin-bedded upper Taman suggests that the MX-82-37 horizon as well as all or at least part of the *Mazapilites* Zone of Cantu Chapa is assignable to the upper Tithonian (see p. 10). On new unpaved road north of Río Moctezuma and above north side of Taman; north-northwest of hanging foot bridge over the Río Moctezuma.

Baja California Sur; Vizcaino Peninsula; Eugenia Formation

BJV-20. Volcanogenic member (lower member) of Eugenia Formation (Barnes, 1982). Olistostromal unit bearing limestone nodules containing common *Buchia piochii* (Gabb, 1869) and associated Zone 4 Radiolaria. Underlying pillowed andesitic basalt flow and *Eugenia* strata of Berriasian to early Hauterivian (Zone 5) age. East of road and near mouth of Arroyo Amargura at coast.

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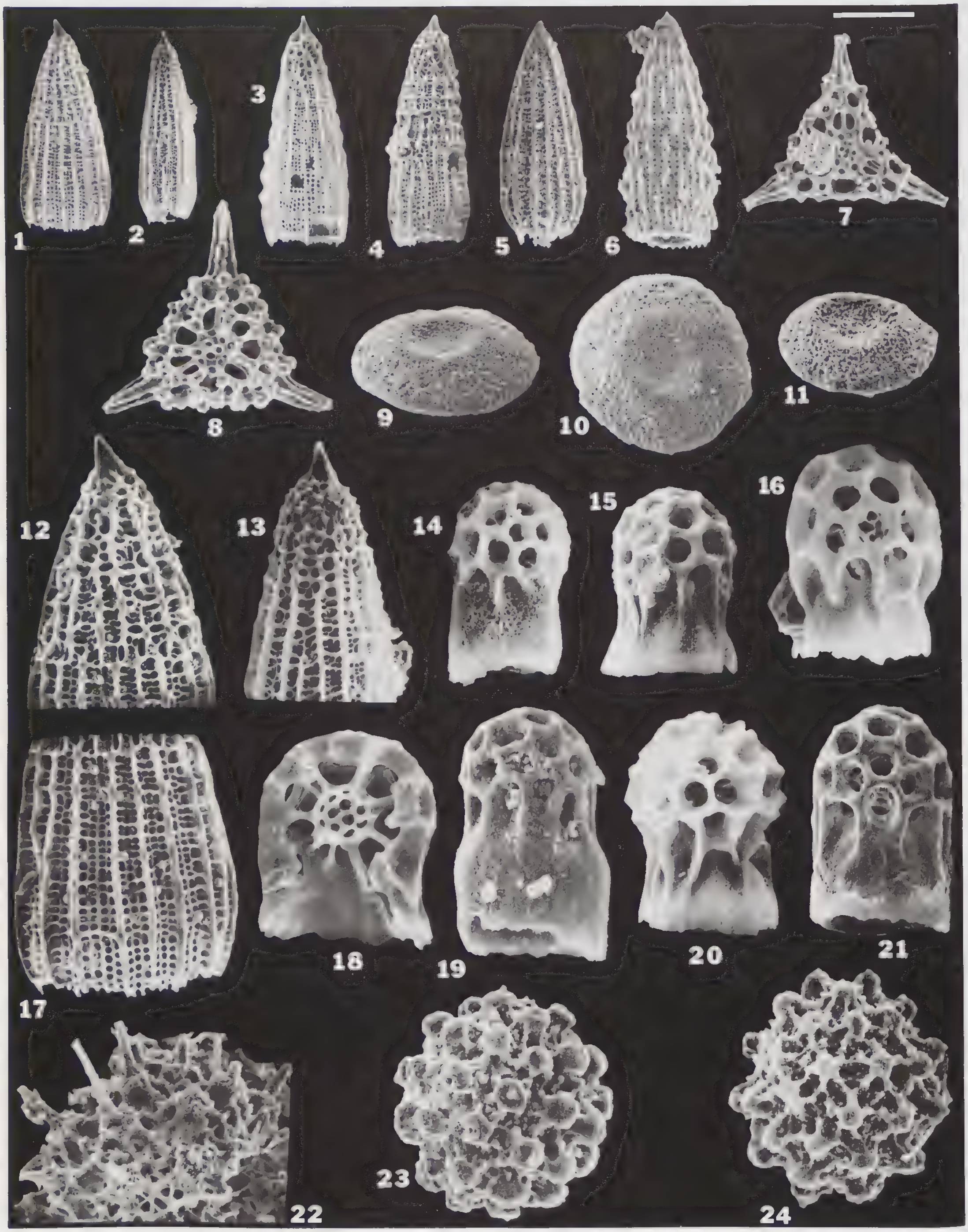
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EXPLANATION OF PLATE 1

All figures are scanning electron micrographs of Upper Jurassic Radiolaria. Scale bar (upper right) is used as a reference for the magnification of all figures.

Figure — Page

1–4, 12, 13, 17. ***Hsuum mclaughlini*** Pessagno and Blome, new species 25
Volcanogenic-pelagic strata overlying the Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. SA-43B: Lower part of Zone 4; upper Tithonian.
Diagnostic characters.—Test rounded apically with short, massive horn. Dense outer latticed layer formed from costal projections obscuring inner latticed layer on proximal one-quarter to one-half of test. Costae straight, often bifurcating.
1, 12, 17. Holotype (USNM 340257). Scale bar = 120, 75, 75 μm respectively. Note density of outer latticed layer proximally, caused by numerous costal projections.
2, 13, 3, 4. Paratypes (Pessagno Collection). Scale bar = 198, 66, 150, 171 μm respectively.

5. ***Hsuum cuestaense*** Pessagno, 1977a 25
Holotype (USNM 21976). Volcanogenic-pelagic strata overlying Coast Range ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-907: Zone 2; Kimmeridgian. Scale bar = 171 μm.
Diagnostic characters.—Test pointed apically with short horn. Outer latticed layer not dense, costal projections not strongly developed. Costae straight, massive, and quite continuous.

6. ***Hsuum maxwelli*** Pessagno, 1977a 25
Holotype (USNM 21980). Same location as in figs. 1–4 above. loc. NSF-973: Zone 2; Kimmeridgian. Scale bar = 99 μm.
Diagnostic characters.—Test narrow, somewhat rounded apically with very short horn. Outer latticed layer not dense with few costal projections. Costae short, staggered, discontinuous.

7. ***Perispyridium ordinarium*** (Pessagno, 1977a) 24
Holotype (USNM 21972). Same location as in fig. 5 above. loc. NSF-908: Zone 3; lower Tithonian? Scale bar = 99 μm.
Diagnostic characters.—Cephalis globular, large for genus. Peripheral latticed shell flat, weakly nodose, thin, markedly triangular in outline. Apical and primary lateral spines outside of peripheral shell triradiate (axial section), of medium length, bluntly terminating. Six large pericephalic pores. Pericephalic pores in areas between spines extending to edge of test.

8. ***Perispyridium tamanense*** Pessagno and Blome, 1982 24
Holotype (USNM 319127). Taman Formation. loc. MX-81-54: Near Tamazunchale, San Luis Potosí, Mexico; Lower Tithonian part of Zone 3. Note specimen is replaced by pyrite. Scale bar = 99 μm.
Diagnostic characters.—Cephalis globular, medium sized. Peripheral latticed shell rounded, subtriangular in outline, wide for genus, with very massive knoblike nodes at pore frame vertices. Apical and primary lateral spines outside of peripheral latticed shell triradiate (axial section), pointed.

9–11. ***Orbiculiforma lowreyensis*** Pessagno, 1977a 22
Great Valley sequence; upper part of *Buchia piochii* Zone of Jones *et al.*, 1969. loc. NSF-823: Zone 4; upper Tithonian. Middle Fork of Elder Creek, Tehama Co., California.
Diagnostic characters.—Medium sized, relatively shallow central cavity. Test periphery angled. Surface of test sloping steeply between the central cavity and the periphery.
9, 10. Holotype (USNM 21960). Scale bar = 120 μm.
11. Paratype (USNM 21961). Scale bar = 150 μm.

14–16, 18, 19, 21. ***Vallupus hopsoni*** Pessagno and Blome, new species 23
Same location as in figs. 1–4 above. loc. SA-43B: Lower part of Zone 4; upper Tithonian.
Diagnostic characters.—Test with single medullary shell having fragile pentagonal and hexagonal pore frames. Cortical shell with massive pentagonal and hexagonal pore frames lacking nodes at vertices and with prominent, imperforate, cylindrical collar-like structure having circular aperture. Pore frames tending to become more elongate at junction with collar.
14–16, 18, 19. Paratypes (Pessagno Collection). Note collar-like structure on cortical shell and presence of single medullary shell. Scale bar = 48, 42, 39, 36, 42 μm respectively.
21. Holotype (USNM 340255). Scale bar = 42 μm.

20. ***Vallupus*** species A 23
Same locality as in figs. 1–4 above. loc. SA-43B: Lower part of Zone 4; upper Tithonian. Scale bar = 48 μm.

22–24. ***Praeconocaryomma immodica*** Pessagno and Poisson, 1981 24
Diagnostic characters.—Cortical shell with prominent mammae which tend to be very high in relief. Mammae pentagonal in outline. First medullary shell with meshwork comprised of equilateral triangular pore frames.
22. Specimen from volcanogenic-pelagic strata overlying Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. NSF-973: Zone 2; Kimmeridgian. Scale bar = 75 μm.
23. Holotype (USNM 264005). From radiolarian chert in Franciscan Complex, Mendocino Co., California. loc. BK-605: Upper part of Zone 1; lower Kimmeridgian? Scale bar = 60 μm.
24. Paratype (USNM 264006). Same location as cited for fig. 23. loc. BK-605. Scale bar = 75 μm.

EXPLANATION OF PLATE 2

All figures are scanning electron micrographs of Upper Jurassic Radiolaria (Nassellariina) from volcanogenic-pelagic strata associated with the Coast Range ophiolite, California Coast Ranges. Scale bar (upper right) is used as a reference for the magnification of all figures.

Figure — Page

1–3, 10, 13, 17, 21–23. ***Mirifusus baileyi*** Pessagno, 1977a 26

Diagnostic characters.—Test thick, consisting of three latticed layers: an inner layer of pentagonal pore frames and two outer layers of triangular pore frames. Outer latticed layer of first eight post-abdominal chambers lacking discrete circumferential ridges, consisting of massive nodes interconnected by bars to form triangular pore frames; outer layer of remaining post-abdominal chambers with two staggered rows of triangular pore frames inserted between closely spaced, generally wide and massive, nodose circumferential ridges.

1, 21, 23. Holotype (USNM 21992). Strata overlying ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Arrow (fig. 21) points to inner layer of triangular meshwork. Lower part of Zone 3; lower Tithonian? Scale bar = 240, 75, 66 μm respectively.

2, 13, 17, 22. Specimens from strata overlying ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. Specimen in fig. 2 malformed due to probable injury during growth. Specimens in fig. 13 and 17 show innermost layer of pentagonal pore frames. Specimen in fig. 22 lacks outer layers of triangular meshwork distally. loc. SA-43B: Lower part of Zone 4; upper Tithonian. Scale bar = 171, 171, 99, 99 μm respectively.

3. Specimen from red manganiferous chert interbedded with vesicular basalts in ophiolite at Wilbur Springs, Colusa Co., California. loc. NSF-997: Zone 3; lower Tithonian? Scale bar = 198 μm.

10. Topotype from strata overlying ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 198 μm.

4, 5, 18, 19. ***Mirifusus mediodilatata*** (Rüst, 1885) 26

Diagnostic characters.—Test wall thin, consisting of an inner latticed layer of pentagonal pore frames. Pore frames of inner latticed layer inserted in two staggered rows between narrow, slightly nodose circumferential ridges. Partially formed outer (second) latticed layer consisting of rods and interconnecting bars which combine to form triangular pore frames apically. Circumferential ridges usually more widely separated than with *M. baileyi* Pessagno, 1977a.

4, 19, 5, 18. Specimens from strata overlying ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 240, 150, 240, 99 μm respectively.

6–8, 11, 20. ***Parvicingula colemani*** Pessagno and Blome, new species 27

Strata overlying ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. SA-43B: Lower part of Zone 4; upper Tithonian.

Diagnostic characters.—Test elongate, cylindrical to subcylindrical, blunt apically with short, massive horn. Eleven to fourteen post-abdominal chambers. Massive, irregular polygonal pore frames on cephalis, thorax, and abdomen. Post-abdominal chambers separated by weakly developed circumferential ridges.

9, 11. Holotype (USNM 340259). Scale bar = 171, 66 μm.

7, 8, 20. Paratypes (Pessagno Collection). Scale bar = 171, 150, 48 μm respectively.

9. ***Napora lospensis*** Pessagno, 1977a 24

Topotype from strata overlying ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-907: Zone 2; Kimmeridgian. Scale bar = 54 μm.

Diagnostic characters.—Massive pore frames; short, massive horn; short massive, incurved feet.

12, 16, 24. ***Mirifusus guadalupensis*** Pessagno, 1977a 26

Specimens from strata overlying ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-907: Zone 2; Kimmeridgian.

Diagnostic characters.—Test comprised of two latticed layers. Inner latticed layer of post-abdominal chambers composed of three rows of very small tetragonal, pentagonal, and hexagonal pore frames set between massive, closely spaced, often quite nodose, circumferential ridges. Outer layer of latticed meshwork on post-abdominal chambers consisting of triangular pore frames formed by thin bars connecting with nodes on circumferential ridges.

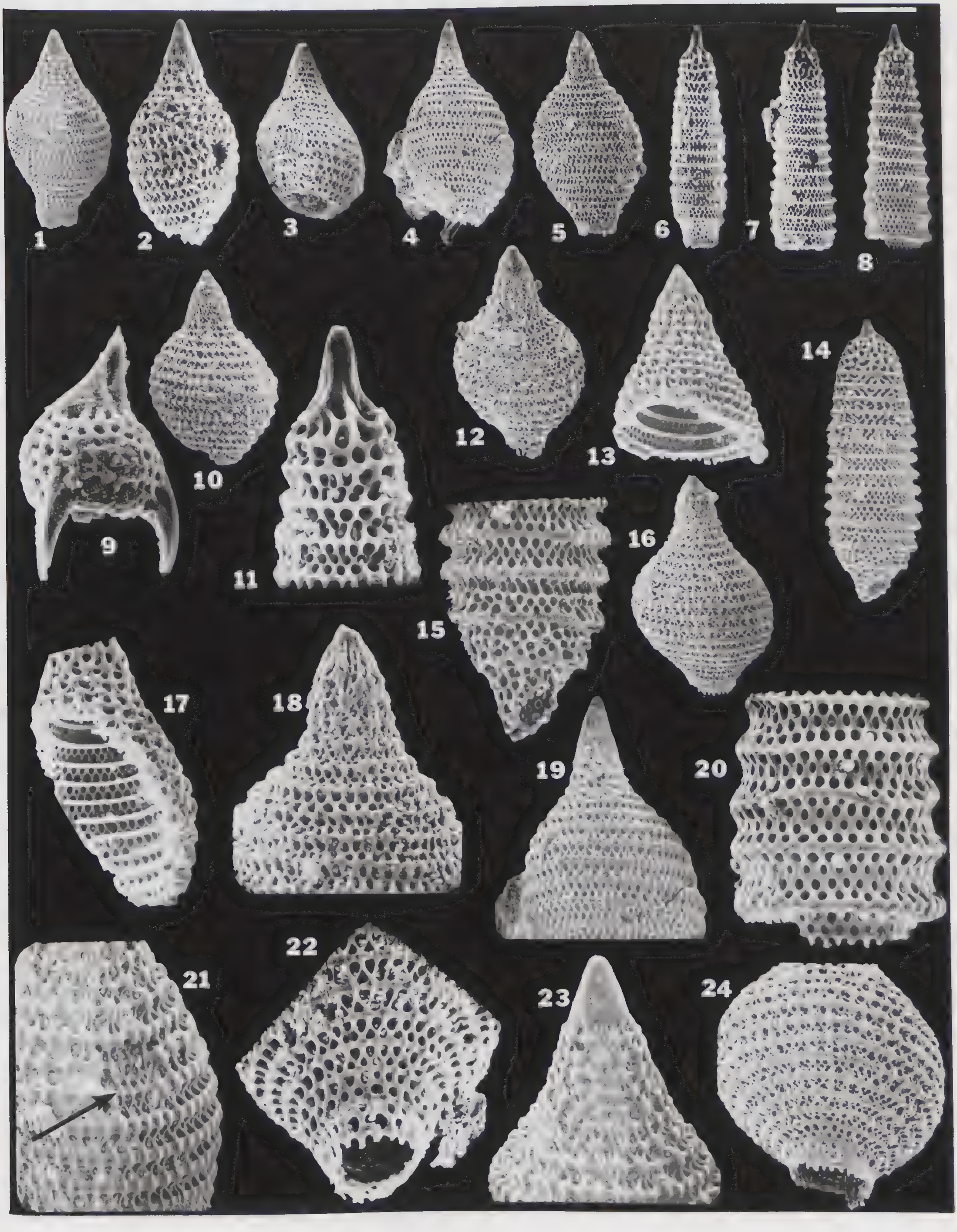
12. Paratype (USNM 21995). Scale bar = 150 μm.

16, 24. Holotype (USNM 21994). Scale bar = 198, 120 μm.

14, 15. ***Parvicingula blowi*** Pessagno, 1977a 26

Holotype (USNM 21984). Strata overlying ophiolite at Point Sal, Santa Barbara Co., California. Scale bar = 150, 84 μm.

Diagnostic characters.—Test short, cylindrical; dome-shaped, broad apically with short horn. Eleven to fourteen post-abdominal chambers. Cephalis, thorax, abdomen, and usually first two post-abdominal chambers with irregular, massive, polygonal pore frames. Remaining post-abdominal chambers with pentagonal pore frames arranged in three (rarely four) rows between circumferential ridges. Circumferential ridges becoming more strongly developed in a distal direction.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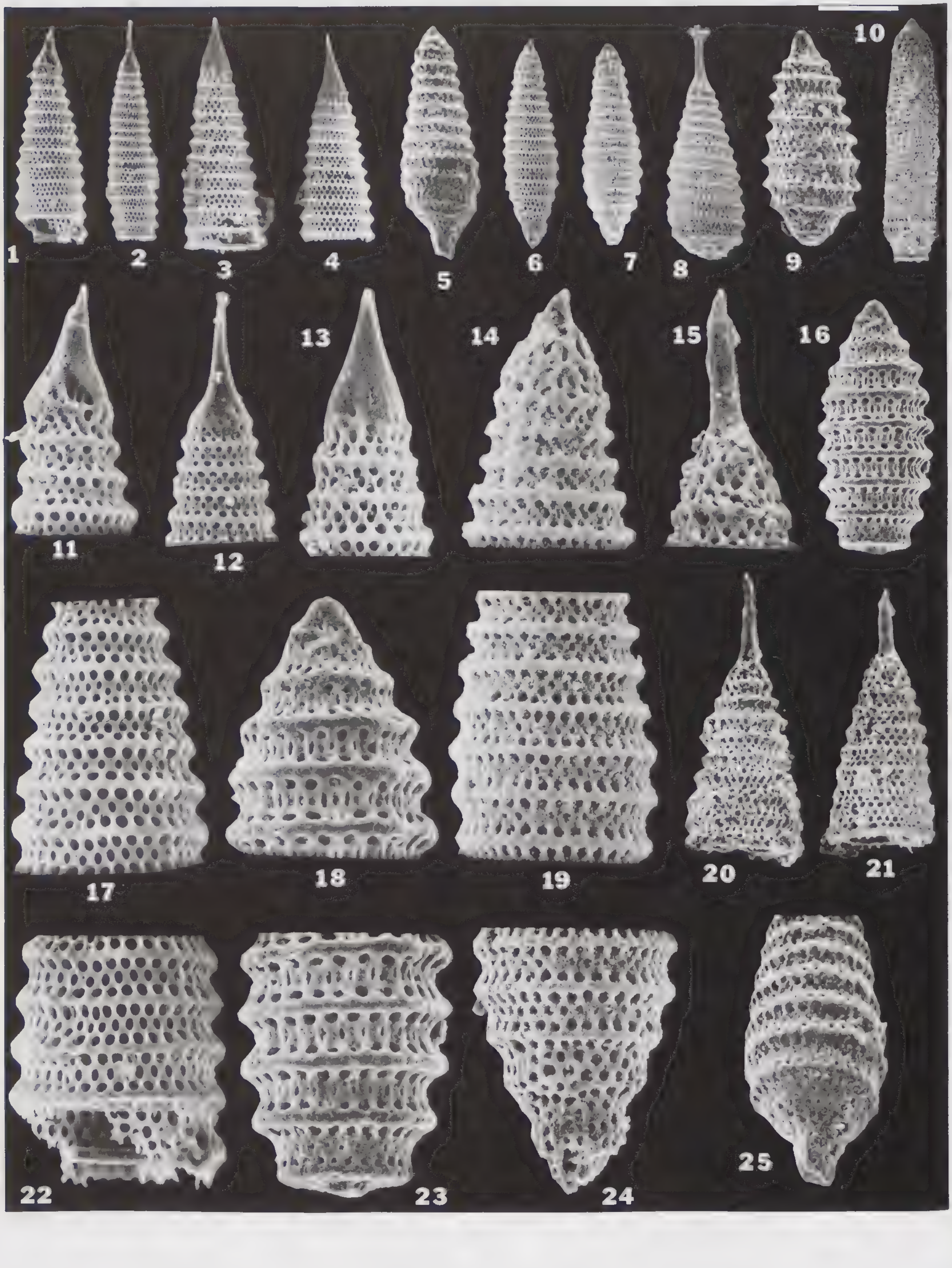
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EXPLANATION OF PLATE 3

All figures are scanning electron micrographs of Radiolaria (Nassellariina) from the California Coast Ranges. Scale bar (upper right) is used as a reference for the magnification of all figures.

Figure — Page

1–4, 11–13, 17, 22. ***Parvicingula excelsa*** Pessagno and Blome, new species 27

Specimens from volcanogenic-pelagic strata overlying the Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. SA-43B: Lower part of Zone 4; upper Tithonian.

Diagnostic characters.—Test elongate, conical with massive, moderately long, conical, pointed horn. Apical portion of test (cephalis through abdomen) inflated, turret-like in aspect. Post-abdominal chambers with three rows of hexagonal pore frames inserted between well-developed, weakly nodose circumferential ridges. Most complete tests with up to fifteen post-abdominal chambers.

1, 11, 17, 22. Holotype (USNM 340261). Note inflated nature of test proximally with outer layer of microgranular silica covering latticed meshwork beneath (figs. 1, 11). Scale bar = 171, 54, 54, 54 μm respectively.

2, 12, 3, 13. Paratypes (Pessagno Collection). Scale bar = 198, 66, 132, 48 μm respectively.

4. Topotype destroyed during SEM work. Scale bar = 150 μm.

5–7, 14, 19, 24, 25. ***Parvicingula jonesi*** Pessagno, 1977b 28

Note all specimens replaced by calcite.

Diagnostic characters.—Test fusiform, dome-shaped apically with short horn and well-developed narrow terminal tube on final post-abdominal chamber. Post-abdominal chambers with three rows of pentagonal pore frames inserted between weakly nodose, prominent circumferential ridges. Eight to eleven post-abdominal chambers.

5, 25. Holotype (USNM 242813). Great Valley sequence at loc. NSF-823, Tehama Co., California. Upper part of *Buchia piochii* Zone. Upper part of radiolarian Zone 4. Scale bar = 120, 75 μm.

6, 14, 19, 24. Specimen from Great Valley sequence at loc. MG-77-3, Napa Co., California. Lower part of *B. piochii* Zone? Middle part of radiolarian Zone 4; upper Tithonian. Scale bar = 198, 48, 48, 48 μm respectively.

7. Topotype. See fig. 5 above. Scale bar = 198 μm.

8. ***Parvicingula santabarbaraensis*** Pessagno, 1977a 28

Holotype (USNM 21990) from volcanogenic-pelagic strata overlying Coast Range ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 150 μm.

Diagnostic characters.—Test broad, conical, pointed apically with massive, long horn terminating in crown-like mass where horn branches and forms four rays. Post-abdominal chambers with three rows of hexagonal pore frames inserted between well-developed, weakly nodose circumferential ridges. Well-preserved specimens with ten to fifteen post-abdominal chambers and long, narrow terminal tube on final post-abdominal chamber.

9. ***Ristola boesii*** (Parona, 1890) ***sensu lato*** 28

Great Valley sequence at loc. NSF-1068, Tehama Co., California. *Buchia pacifica* Zone (Lower Cret.: lower to middle Valanginian). Radiolarian Zone 5, Subzone 5B. Specimen not as rounded apically as Parona's type; replaced by calcite. Scale bar = 150 μm.

10. ***Ristola altissima*** (Rüst, 1885) 28

From same location as cited for fig. 8 above. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 300 μm.

Diagnostic characters.—Test long, cylindrical with knoblike apical portion (cephalis through thorax) which lacks a horn. Proximal portion of test sometimes somewhat inflated on some specimens. Post-abdominal chambers with three rows of small, hexagonal pore frames inserted between very closely spaced, highly nodose circumferential ridges. Up to twenty-seven post-abdominal chambers present on complete specimens. Final post-abdominal chamber with broad terminal tube.

15, 20, 21. ***Parvicingula vera*** Pessagno and Whalen, 1982 28

Diagnostic characters.—Test broad, conical with long, thick, massive, pointed horn. Post-abdominal chambers with three rows of hexagonal pore frames inserted between weakly developed circumferential ridges. Usually six to eight post-abdominal chambers.

15, 21. Holotype (USNM 307268) from upper member of Snowshoe Formation, John Day Inlier, east-central Oregon. loc. OR-501C; uppermost Bathonian. Scale bar = 48, 159 μm.

20. Specimen from lower, massively bedded part of Taman Formation near Tamazunchale, San Luis Potosí, east-central Mexico. loc. MX-80-23; Kimmeridgian. Scale bar = 99 μm.

16, 18, 23. ***Ristola*** sp. aff. ***R. boesii*** (Parona, 1890) 29

Calcified specimen from Great Valley sequence at loc. NSF-845, McCarty Creek, Tehama Co., California. Upper part of *Buchia pacifica* Zone (Lower Cret.: middle Valanginian). Scale bar = 99, 48, 48 μm respectively.

EXPLANATION OF PLATE 4

All figures are scanning electron micrographs of Radiolaria (Nassellariina) from the California Coast Ranges. Scale bar (upper right) is used as a reference for the magnification of all figures.

Figure — Page

1. ***"Hsuum" stanleyense*** Pessagno, 1977a 31
Holotype (USNM 21982). From volcanogenic-pelagic strata above the Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. NSF-973: Zone 2; Kimmeridgian. Scale bar = 120 μm.
Diagnostic characters.—Test conical with short horn. Single latticed layer composed of linearly arranged square pore frames with nodes at corners. Not showing two layers of latticed meshwork as typical of *Hsuum* Pessagno, 1977a; costae and costal projections absent.

2, 3. ***Ristola hsui*** Pessagno, 1977a 29
From volcanogenic-pelagic strata above Coast Range ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian?
Diagnostic characters.—Test conical lacking a horn. Pore frames of post-abdominal chambers arranged in three rows inserted between nodose ("H-linked") circumferential ridges. Two flanking rows of pore frames pentagonal in shape, steeply sloping away from circumferential ridges. Central row of pore frames tetragonal in shape, smaller in size. Seven to eight post-abdominal chambers. Final post-abdominal chamber with a tubular projection.
2. Holotype (USNM 21986). Scale bar = 120 μm.
3. Paratype (Pessagno Collection). Scale bar = 99 μm.

4, 11. ***Saitoum pagei*** Pessagno, 1977a 30
Holotype (USNM 22006). Same location as cited for fig. 2 above. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 75, 60 μm.
Diagnostic characters.—Test monocyrtid with short triradiate horn and three long, incurved, triradiate feet. Test with circular to subcircular pores set in widely spaced tetragonal and triangular pore frames.

5. ***Obesacapsula morroensis*** Pessagno, 1977a 29
Holotype (USNM 21996). Same location as cited for fig. 2 above. loc. NSF-907: Zone 2; Kimmeridgian. Scale bar = 198 μm.
Diagnostic characters.—Proximal portion of test (cephalis to third post-abdominal chamber) conical. Fourth post-abdominal chamber quite large and globular forming three-quarters of test. Wide, tubular, cylindrical extension occurring on fourth post-abdominal chamber. Meshwork irregular, spongy.

6. ***Ristola procera*** (Pessagno, 1977a) 29
Holotype (USNM 21988). Same location as cited for fig. 2 above. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 240 μm.
Diagnostic characters.—Test extremely elongate when complete, conical apically. Most of test cylindrical. Post-abdominal chambers closely spaced, numerous (thirty-three or more) with three rows of uniformly sized hexagonal pore frames between circumferential ridges. Circumferential ridges thin, nodose, closely spaced.

7, 17. ***Ristola*** sp. cf. ***R. boesii*** (Parona, 1890) 29
From volcanogenic-pelagic strata above Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. SA-43B: Lower part of Zone 4; upper Tithonian. Scale bar = 120, 60 μm.

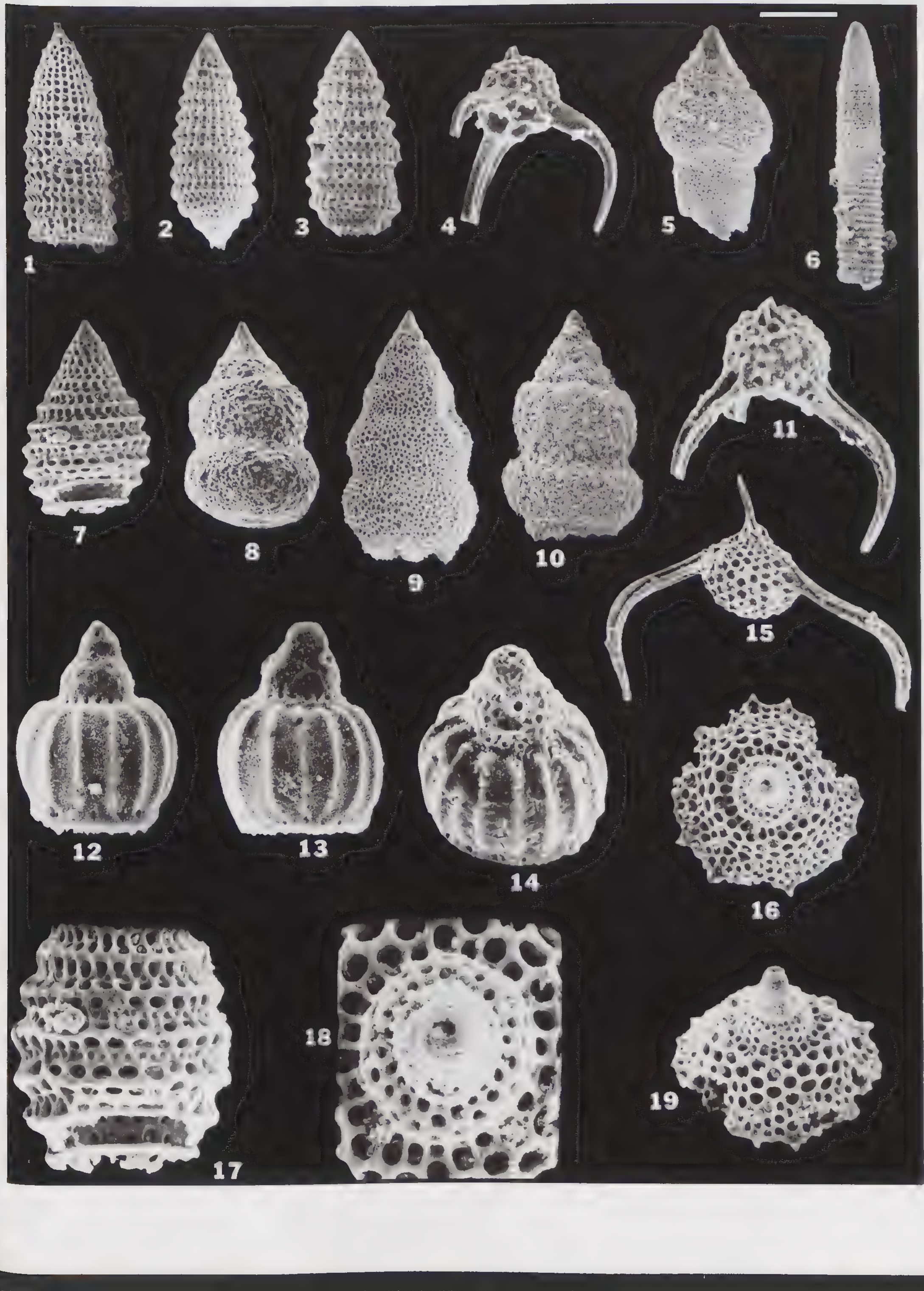
8, 10. ***Obesacapsula rotunda*** (Hinde, 1902) 29
Diagnostic characters.—Apical portion of test (cephalis through second post-abdominal chamber) conical. Pronounced (deep) strictures separating second from third and third from fourth post-abdominal chambers. Final post-abdominal chambers quite inflated.
8. Specimen calcified. From Great Valley sequence at McCarty Creek, Tehama Co., California. loc. NSF-845: Upper part of *Buchia pacifica* Zone; middle Valanginian. Radiolarian Zone 5, Subzone 5B. Scale bar = 198 μm.
10. Pyritized specimen from Great Valley sequence at McCarty Creek, Tehama Co., California. loc. NSF-1019: Upper part of *Buchia keyserlingi* Zone; upper Valanginian. Radiolarian Zone 5, Subzone 5C. Scale bar = 198 μm.

9. ***Obesacapsula*** sp. aff. ***O. rotunda*** (Hinde, 1902) 30
Specimen from volcanogenic-pelagic strata overlying Coast Range ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 300 μm.

12–14. ***"Eucyrtidium" ptyctum*** Riedel and Sanfilippo, 1974 30
From volcanogenic-pelagic strata above Coast Range ophiolite. Note pores in strictures and presence of a cephalopyle (figs. 13, 14).
Diagnostic characters.—Test tricyrtid. Weakly developed stricture between cephalis and thorax; prominent stricture between thorax and abdomen. Rows of circular pores occurring in stricture between thorax and abdomen and at base of abdomen. Cephalopyle occurring at base of cephalis. Abdomen with widely spaced, massive costae.
12, 13. Specimens from Alamo Creek, San Luis Obispo Co., California. loc. SA-29: Upper part of Zone 2; Kimmeridgian. Scale bar = 39 μm.
14. Pyritized specimen from Point Sal, Santa Barbara Co., California. loc. NSF-900: upper part of Zone 1(?); Kimmeridgian. Scale bar = 30 μm.

15. ***Turanta flexa*** Pessagno and Blome, 1982 30
Holotype (USNM 319135). Volcanogenic-pelagic strata overlying the Coast Range ophiolite at Point Sal, Santa Barbara Co., California. loc. NSF-908: Lower part of Zone 3; lower Tithonian? Scale bar = 190 μm.
Diagnostic characters.—Long, incurved feet; feet triradiate in axial section. Distal half of one foot displaying curvature outside of equatorial plane of test. Horn short, slender, curved, triradiate in axial section. Thorax with massive hexagonal pore frames.

16, 18, 19. ***Andromeda violae*** Baumgartner, 1980 30
From volcanogenic-pelagic strata overlying Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California. loc. SA-43B: Lower part of Zone 4; upper Tithonian. Scale bar = 120, 48, 108 μm respectively.
Diagnostic characters.—Test multicyrtid, hat-shaped with pronounced shelf-like stricture separating last two post-abdominal chambers. Pore frames tetragonal, pentagonal, and hexagonal; increasing in size in a distal direction.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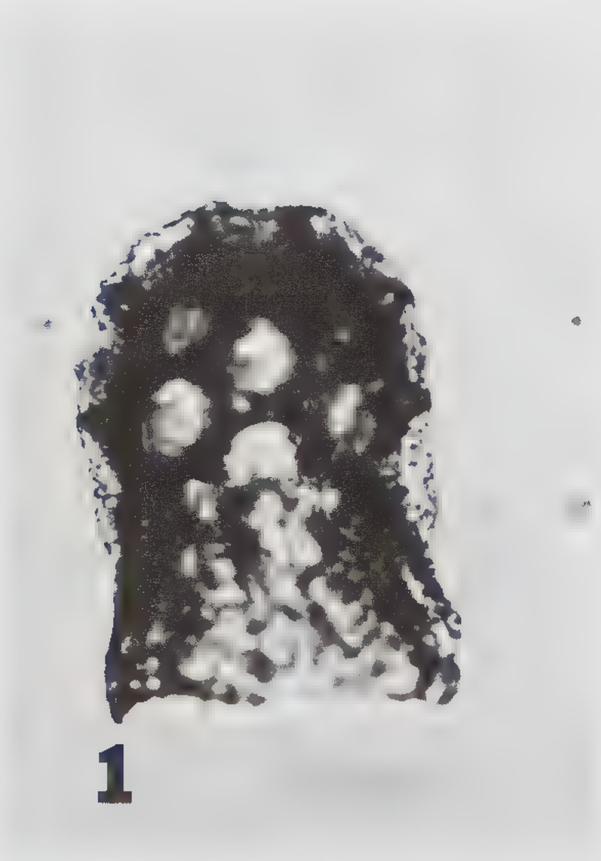
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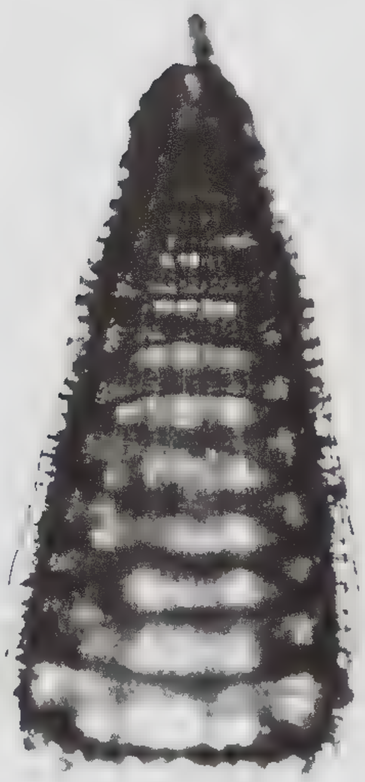
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EXPLANATION OF PLATE 5

All figures are transmitted light micrographs of Upper Jurassic Radiolaria from volcanogenic-pelagic strata overlying the Coast Range ophiolite (Stanley Mt. remnant) at Alamo Creek, San Luis Obispo Co., California.

Figure — Page

1. ***Vallupus hopsoni*** Pessagno and Blome, new species 23
   Paratype slide (USNM 340256). loc. SA-43B: Lower part of Zone 4; upper part of lower Tithonian or lowermost part of upper Tithonian. Length of specimen = 260 μm.

2, 3. ***Parvicingula colemani*** Pessagno and Blome, new species 27
   Paratype slide (USNM 340260). See fig. 1 above. loc. SA-43B.
   2. Length of specimen (exclusive of horn) = 420 μm.
   3. Length of specimen (exclusive of horn) = 450 μm.

4, 5. ***Parvicingula excelsa*** Pessagno and Blome, new species 27
   Paratype slide (USNM 340262). See fig. 1 above. loc. SA-43B.
   4. Length of specimen (exclusive of horn) = 425 μm.
   5. Length of specimen (exclusive of horn) = 400 μm.

6. ***Hsuum mclaughlini*** Pessagno and Blome, new species 25
   Paratype slide (USNM 340258). See fig. 1 above. loc. SA-43B. Length of specimen (exclusive of horn) = 425 μm.

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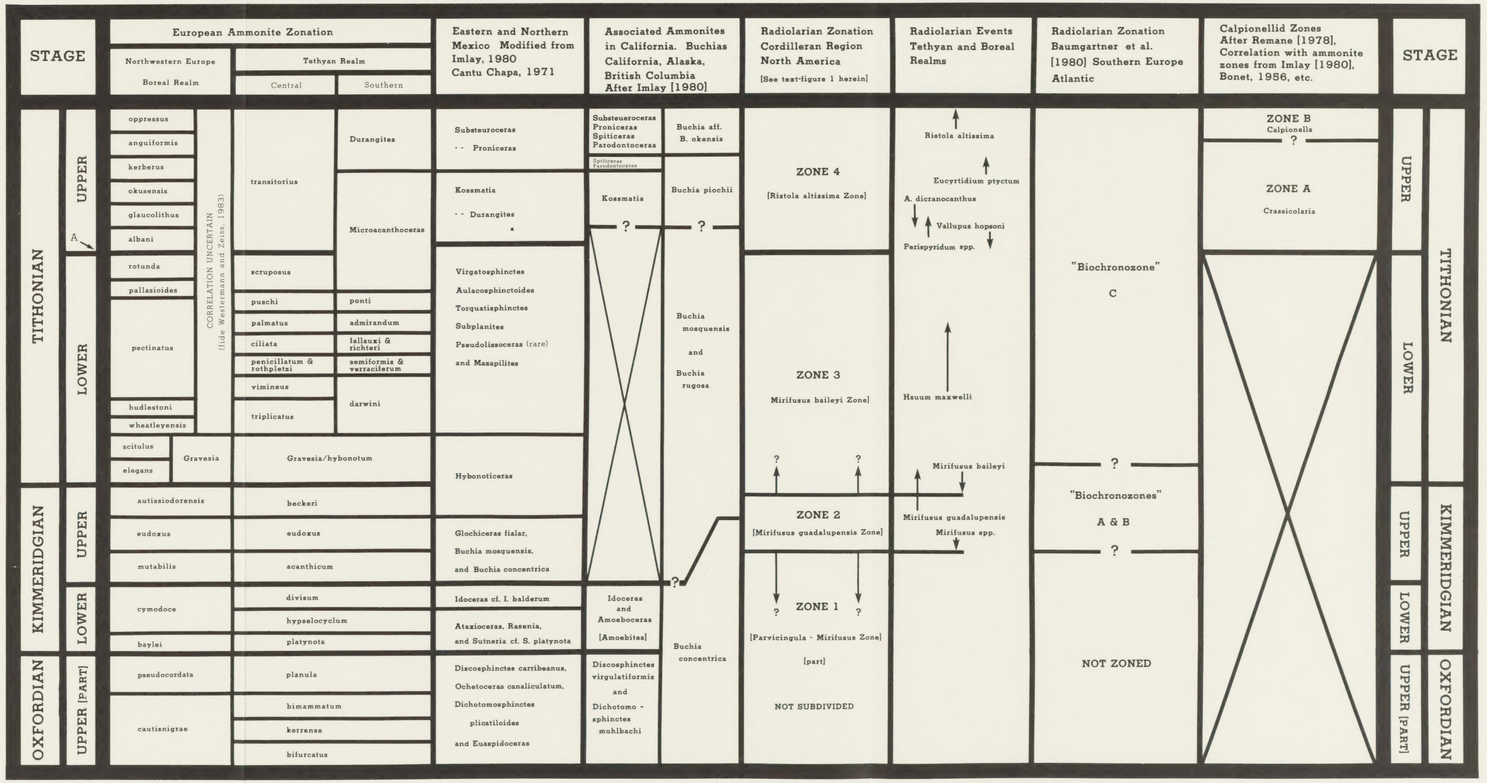
Text-figure 3.—Ammonite zonation for northwestern Europe (Boreal Realm) [after Casey (1973), Cope (1978), Wimbledon and Cope (1978) and Zeiss and Westermann (written commun., 1983)] and central and southern Europe (Tethyan Realm) [after Enay and Geyssant (1975), Oloriz and Tavera (1981), Oloriz (1981), Zeiss (1977, 1979), Ohmert and Zeiss (1980), and Zeiss and Westermann (written commun., 1983)].

Note that we define the base of the upper Tithonian by the first occurrence of hyaline calpionellids [A = base of calpionellid Zone A/*Crassicollaria* Zone of Remane (1969, 1978)]. Also note that the correlation of Tithonian ammonite zones between Boreal northwestern Europe and Tethyan central and southern Europe is uncertain (Zeiss and Westermann, written commun., 1983). In Boreal northwestern Europe, we follow Imlay (1980, p. 34) in placing the base of the upper Tithonian at the base of the *albani* Zone. However, we realize that due to the absence of calpionellids in boreal strata this assignment is only tentative. The use of radiolarian taxa that make their first appearance at the base of calpionellid Zone A in the European Tethys and that likewise occur in the European Boreal Realm may help to resolve this problem.

In the northern Tethyan Realm of northeastern and east-central Mexico it can be established that the base of calpionellid Zone A occurs below the *Kossmatia–Durangites* Assemblage of Imlay (1980) and includes all or part of the *Mazapilites* Zone of Cantu Chapa (1971). At the village of Taman, San Luis Potosi, the lower part of the upper thin-bedded portion of the Taman Formation (= lower part of Pimienta Formation of Cantu Chapa) includes the *Mazapilites* Zone as well as Radiolaria assignable to the lower part of Zone 4. Elsewhere in this area Longoria records minute hyaline calpionellids at the same horizon. These findings seem to be confirmed by those of Imlay (1980, p. 34) in the Sierra Cruillas, Tamaulipas. Imlay indicates that Bonet (1956) found calpionellids just below a sequence containing the *Kossmatia–Durangites* Assemblage.

TEXT FIGURE 3 [A = FIRST OCCURENCE OF CALPIONELLIDS]



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Collinson, J.
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